Vol. XXXIX. JUNE, 1898.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

No. 830.

MOVABLE DAMS.

By B. F. Thomas, M. Am. Soc. C. E.

Presented March 16th, 1898.

WITH DISCUSSION.

General Statement.

Some twelve or fourteen years since, the author, as Assistant Engineer to the late Major James C. Post, was directed to thoroughly investigate the subject of movable dams, as applied in Europe and in this country, with a view to their adoption on certain small rivers in the district under his charge.

The investigation resulted in the accumulation of a great amount of material from widely scattered sources, in treatises, reports, pamphlets, magazine and newspaper articles, etc., and valuable information from actual observation of the dams in use on the Ohio and Great Kanawha Rivers.

The object of this paper is to digest and present the information thus collected in as concise shape as practicable in connection with a description, more in detail, of the needle dam recently completed by the author on the Big Sandy River at Louisa, Ky., and incidentally to make a plea for a more satisfactory solution of the problem of

river improvement by the construction of movable dams of higher lift on American rivers.

Classes and Kinds.—Movable dams may be divided into two general classes: (1) those requiring extraneous power for their maneuvers, and (2) those operated by the force of water properly applied. Among the first class may be named the various types of trestle and wicket dam, like the Poirée, Chanoine, Boulé, Cameré, etc., while the second class comprises the several forms of bear-trap, drum-wickets, etc. The first class is practically the only one so far applied to navigable rivers, and its application has been confined largely to the wicket of Chanoine and the trestle and needle of Poirée. In general these dams are constructed in two or more sections, in addition to the lock, which all dams must have. One of these is for navigation, called the pass, and one or more for the passage of surplus water, called the weir. The sill of the pass is generally placed below original low-water mark; those of the weirs conform closely to the bed of the river and are generally considerably higher than that of the pass. The forms of closing are many, and frequently vary on the same dam; for instance, the pass may be of wickets and the weir of needles, or the reverse may be the case; however, there are many dams wholly of wickets, but none, so far as known to the author, wholly of needles except the one heretofore mentioned, in this country.

More than one type has been applied, even on the same part of a dam; for instance, at Suresnes, France, the pass is closed by trestles supporting alternate bays of Boulé gates and Cameré curtains.

The Chanoine wicket is a heavy upright door hinged below its middle to a horse connecting with a floor and also to a prop which rests against a shoe on the floor. The removal of the support of the prop permits the wicket to fall with the current.

On the smaller rivers, generally, the Chanoine wicket has come into use for at least one part of the dam, and in almost all cases such dams are operated from foot-bridges made of Poirée trestles; practically a double construction. Formerly Chanoine dams were raised from a boat, but this method has been superseded by the foot-bridge, except on wide rivers.

In the needle dam the water is dammed up by planks, called needles, resting against bars connecting the trestles at the top, and against a sill in the river-bed at the bottom. The trestles are spaced

from 3 to 4 ft. apart, and when not in use lie down across the stream, being protected from injury by the sill mentioned. A walkway connects all the trestles when standing. The needles are generally of small dimensions and are placed by hand. The Boulé gate and Cameré curtain replace the needles by small gates and curtains resting directly against the trestles or against uprights leaning on the trestles. In the overhead-bridge dam the supports are all drawn up to the bridge when not in use, and their bottoms rest against a sill in the river-bed when in use.

Object and Advantages.—The solution of the problem of improving rivers of moderate flow can be attained most satisfactorily by the construction of high-lift movable dams. This simply means the application of heavier parts to hold back the water, and heavier machinery with which to perform the operations, than are now in use. The purpose of movable dams is to conserve the water in a stream during the season of medium flow, so that navigation may go on uninterruptedly through the lock, and restore the stream to its natural condition again (by lowering the dams) upon the approach of sufficient water for free navigation.

In the latter respect, movable dams are a great improvement over fixed dams, in which navigation must pass through the lock at all times. Another advantage they possess over fixed dams, which, however, seems to have been lost sight of, is that they are applicable to higher lifts, because they do not raise the level of the water during freshets above its accustomed height in the original condition of the river. While this is a fact, yet these dams have not been applied even to equal lifts with those of fixed dams, and their greatest drawback has been that their cost was far too great for the amount of river made navigable thereby; in other words the lift attained was too small to justify the expense. The success of movable dams cannot be considered complete until they have been applied to lifts at least equal to those which would be given to fixed dams at the same points, and at no greater cost.

In many rivers where the banks are of good height, it is believed to be possible to reduce the number of dams to half that now proposed, and still adhere to types which have had ample trial and are well known. The American needle dam which has been mentioned sustains a head of 12 ft. for months, and yet it is maneuvered with simple appliances and with as great facility as are the needle dams of

France with heads of 5 to 7 ft. Its operation would be quite as easy with a much greater depth on the sill, provided the lift was not proportionately increased. That the lift of Chanoine dams can be increased to 12 ft., with wickets 18 to 20 ft. high, the author has no doubt, particularly if a suitably designed tripping device is used which will admit of a more rigid prop and horse construction.

The Boulé gate may also be readily applied to high lifts in rivers where there is ample time for the maneuvers, and the overhead-bridge dam is already in use for high dams.

The author does not claim any expert knowledge on the subject, and hopes to see open criticism of his opinions from those of wider experience and maturer thought, but he has successfully applied needles as above stated, and his investigations have convinced him that other systems may be applied to much higher lifts than heretofore, with vast economy in the first cost as well as in the future operation and maintenance, and to the great benefit of navigation, which will then not be troubled by the delay and danger incident to passing through so many locks.

While the present forms of dam can be applied to greater lifts their maneuvers are attended with more or less danger, and this objection should be overcome in designing a dam with high lift.

The greatest danger to life occurs in lowering the dam, when the water is turned loose and forms a raging torrent from which rescue would be impossible, and this work should not take place from a narrow foot-bridge or maneuvering boat. This should be obviated by the substitution of suitable appliances located on the masonry, and, where possible, the raising should also be done with stationary machinery; but where this is not practicable, it should at least occur in a manner which in no way endangers the lives of the men engaged at it.

Essentials.—The study of this subject has developed in the author's mind the conviction that every movable dam not operated by the natural forces of the water, properly brought into play, should fulfill the following conditions:

(1) The head of water sustained should not be less than that advisable for a stationary dam at the same point.

(2) The dam should be capable of being operated by the regular employees and appliances, both in lowering and raising, under full head, in whole or in part, without risk to the operatives.

(3) The crest should be submersible to a sufficient extent to regulate the flow at ordinary stages.

(4) The leakage should not exceed the discharge of the stream at any season.

(5) The parts should be complete in themselves without the introduction of additional means for sustaining the water, even in low-water seasons.

(6) It should not be necessary to move any part of the structure or its maneuvering appliances to points of safety during or after its lowering.

(7) The cost should not exceed that of a fixed dam for the same location.

As has been stated, several of the types of dam now in use may be made to fill the first condition. The same is also true of the third and possibly of the fourth and fifth, but the second condition is not fulfilled in any dam in use known to the author. It may be that this requirement cannot be met by a single construction, and that a combination would be necessary for the purpose, but the author is of the opinion that a dam made wholly of trestles which could be raised and lowered at right angles to the current, with stationary machinery, would very nearly meet every condition necessary to a successful movable dam.

If a double construction must be resorted to, it should be one in which the raising is done with or across the current, and the lowering down stream. Neither maneuver should be against the current. For instance, a dam consisting wholly of trestles could first be erected from the masonry, and then a dam composed of wickets or shutters could safely be set up in the quiet water thus occasioned, before the trestles would overflow; as soon as the dam proper was up, the trestles could be let down. The lowering of the wickets or shutters could be done with a suitably designed tripping device, operated from the masonry, and their erection could be accomplished also from the masonry with a crab or engine and chain leading out over the trestles and being connected successively with the wicket chains passed over sheaves on the trestle heads, or in the usual manner from the footbridge or a maneuvering boat. In many locations the use of timber and concrete in foundations always submerged would greatly reduce construction expenses. With the abundance of gravel in many

streams, which must be removed in order to build the foundation, and the cheapness of good cement, it is possible to secure an excellent concrete at small cost; and the whole construction is simplified by its use, as, with it, the formation of culverts, the laying of pipes, or the setting of bolts, becomes easy.

For lock faces and exposed surfaces it can, with small additional cost, be shaped to have the appearance of the finest masonry, and the architectural effect of works of this class should not be neglected. Ornamentation is not necessary, in fact, would be out of place; but every part which shows above water, the masonry, the gates, the trestles, the wickets, the operating appliances, the buildings and grounds and fences, should be so designed as to present an appearance at once satisfactory from an artistic as well as from a utilitarian standpoint.

While timber may be advantageously used in deep foundations, it should rarely appear in those parts of the structure which are exposed; and the use of it for guide and protection cribs is to be condemned, because it lasts but a short time and is unsightly. The use of concrete for these structures will about double their first cost, but their renewal will not be necessary.

With the foregoing remarks of a general character, the subject will now be taken up more in detail, prefaced by a brief *résumé* of the condition of river improvement previous to the introduction of movable dams.

History.—A dam is a barrier placed across a water-way for raising its level or diverting its course. Dams are used as aids to navigation, irrigation, the running of machinery, and for the storage of water for domestic and manufacturing purposes. There are two general classes of dams, stationary and movable. A stationary dam is a wall placed across a stream affording no passage for navigation or the discharge of water except over its crest. A movable dam is a barrier placed in a stream and capable of being lowered, when desirable, so as to form no obstruction to navigation or the passage of water.

Mill dams are said to have been in use before the Christian era, and it is known that they were numerous as early as the 5th century, but these dams were a hindrance rather than a help to navigation, as they completely closed the streams, or, when sluices were opened on streams affording sufficient water, they were difficult to ascend and

dangerous to descend. Prior to 1830 the fixed or stationary dam was the only one used for navigation purposes. These had been in use on the Lot since the 13th century, and, with the introduction of locks in the 15th century, had been constructed on many rivers, but they were open to the same objection that exists to-day—the principle is unfavorable to navigation. Dams with navigable passes had been used, but the ascent of the pass was always very laborious and costly. The openings or passes were closed by beams lying one upon another, supported by piles or piers at the ends, or by planks resting against a sill in the river-bed at the bottom, and a beam spanning the opening at the top. When it was desired to open the passage, the beams or planks were removed, either one by one, or simultaneously, and the water rushed through with great violence. Sometimes these beams and planks were used for the purpose of producing artificial floods, by damming up the whole river for a certain time, until the level of the pool above the dam had been raised to a desired height, when, by the sudden removal of the beams or planks, the water escaped and carried rafts or boats over the shallow places below. The operation of letting out the water was called "flushing" or "flashing"; in this country on log streams it is called "splashing." Some falling gates or shutters, supported by props when they were upright, were built across the crest of a fixed dam on the River Orb, in France, in the 18th century, forming the first attempt at placing movable weirs on fixed dams.

The first distinct type of movable dam was erected in the early part of the present century in the Lehigh River, in the United States, and known as the bear-trap dam, but this system has not come into general use. It consisted of two wooden gates revolving on horizontal axes at the floor level. The down-stream gate pointed up stream, and the up-stream one pointed down stream. The up-stream gate rested on the edge of the down-stream gate when raised. The dam was operated by water running under the gates through culverts and forcing them up. A revival of interest in this form of dam has taken place in recent years, and it is believed that results valuable to navigation will follow its re-introduction on American rivers.

Fixed dams were sometimes built with several openings or passages to admit of the regulation of the pool and the passage of timber and boats. A dam was formed of masonry or of timber cribs filled

with earth or stone, or sometimes merely of an embankment of stone protected by water walls. The coping of the dam served to support a foot-bridge carrying a crab for operating the shutters; sometimes several gates were placed in the same line, the width of the opening being divided into several bays by vertical beams, one end of which rested on the floor and the other on the foot-bridge. The gates slid in grooves in the vertical beams. Sometimes, if it was desirable to secure a considerable head of water, several gates were used, one above the other. These were objectionable for the reason that the shutters were too narrow, their supports too close, and the foot-bridges were raised too little a distance above the water to allow traffic to pass under them.

Similar to the old-time stanches were the horizontal *poutrelles*. By the use of these, openings could be made from 15 to 18 ft. wide or more; and, the foot-bridge being dispensed with, by using a sufficient number of beams, considerable height could be secured in the pool; but the beams were very heavy and difficult to manage. To facilitate maneuvering, escapements or escape *poutrelles* were sometimes used, in which one end rested against a beam turning on a vertical axis. The opening of the pass was easy and rapid, but the closing remained difficult. Openings wide enough to allow the passage of rafts and boats could be made by the removal of the beams.

Prior to 1834, the best type of dam known was the masonry ones of the Lot. This was the oldest canalized river. Locks were introduced upon it as soon as they were known. In a distance of 160 miles there are 71 locks with fixed dams, having a total lift of 515 ft. The depth of water on the lower sill is 3 ft. Navigation up to this time had been expensive, slow and uncertain, and no system of movable dams had been invented which tended to solve the difficulty.

In the year 1834, M. Poirée, an eminent French engineer, invented the needle dam. This invention ushered in a new era in navigation, and this type of dam soon multiplied and was improved and modified, and other inventors came forward with entirely new ideas, some good, some bad, until to-day there are numerous systems from which to choose.

As may be imagined, the invention of movable dams in France was only arrived at after long discussion of ways and means for more successfully operating the movable apparatus used for closing the

chutes in the old stationary dams. The use of needles was already old. The problem to be solved was how best to widen the passages to accommodate the increased requirements. The experiment of supporting the tops of the needles by a rope was tried, and was in a measure satisfactory for lifts of 2 to 3 ft. on passes of considerable width. The rope was braced to the down-stream side of the sill by strips of wood. One end of the rope was tied to an anchor, while the other was wound on a windlass. To open the dam it was only necessary to cut the line at the anchor, when the whole set of needles would float out, being attached to the rope beforehand, as were also the braces. This, then, was the status of improvements in fixed dams when the first actual movable dam was constructed, and it was only natural that iron trestles should supersede masonry piers in needle dams, that gates sliding on these same trestles should later on replace the sluice gates of the old chutes operated from an overhead-bridge, that the swinging wickets formerly used to increase the heights of stationary dams should actually form the dam itself in after years, and that *poutrelles* hinged together and supported on trestles should form a curtain dam that was to become famous.

Poirée Needle Dams.

Under this head will be described the needle dam as applied in France, Belgium and the United States. Those of other parts of Europe and South America vary but little from the French pattern.

In France.

While the bear-trap was earlier in use on the Lehigh, yet the pioneer of movable dams on navigable rivers, and the one which has always been in most general use, is the classic needle dam invented by M. Poirée in 1834 and first constructed at Basseville, France. It is called a needle dam because the wall which holds and supports the water is made of needles or wooden spars ranged side by side across the stream.

No better description can be given than that of the inventor himself* ten years after the first dam was built, which is as follows:

"It consists of a row of trestles, placed parallel with the current, turning around their bases, fixed to the floor, and connected with one

* De Lagrene, "*Cours de Navigation Intérieure*," p. 175.

another in the upper part, when they are upright, by clamps or bars having claws at the end. Wooden needles, resting against the up-stream side on a sill at the bottom and on the bars at the top, form the wall which arrests and sustains the water. When all the trestles are bedded they present no obstacle to navigation above the sill of the floor. Each trestle is shaped like a trapezium, the two bases are horizontal, the lower base ends in journals which fit into two boxes of cast iron; the upper base carries the planks of a service-bridge. The up-stream side is vertical, the down-stream one sloping. The inside is furnished with a brace or with other bars according to the strain to be supported. At the head of the trestle is a bolt which carries on its upper side a washer against which rests the up-stream bar, and having on the lower end a cap against which is fitted on one side the curved claw of the hook which unites each trestle to the preceding one, and on the other side the end of the hook which joins it to the one following. Each hook is provided at its extremity with a chain which serves for working it, and the end of the chain is fastened to the cap of the preceding trestle. In order to allow the trestles to be easily worked by two men, they are placed 3.28 ft. apart and are only 6.23 ft. high, 2.56 ft. wide at the top and 4.92 ft. wide at the base. The thickness of the iron is 0.12 ft., and the weight of each trestle is 242 lbs. without the bars and hooks (dimensions of the trestles of the Decize dam, built in 1836). When it is necessary to raise the dam two men take the chain which hangs along the abutment, raise the first trestle, place its hook in the ring fixed in the masonry, lay the two planks on the foot-bridge, and fasten the trestle to the coping by the front and back bars. They work in the same way with the rest of the trestles. The skeleton of the dam being up thus, the two men proceed to fill it in by placing the needles one by one, first one space apart to break the current, then close together to make the wall as tight as possible. If it is desirable to lower the water, the two men take the needles away one at a time and lay them on the back part of the foot-bridge. If it is desirable to remove the trestles, the needles are taken to the storehouse, the bars and planks of the last bay are removed; then the hook is raised which joins the last trestle to the last but one, and it is allowed to fall, the shock being lessened by means of the chain fastened to the hook. The same method is pursued with each bay. When each trestle is laid down and the chain stretched, a ring of particular construction placed at a conveniently determined distance should be on the right of the screw-ring on the trestle still standing; if such is not the case, it shows that the trestle is not on the bottom."

Modifications.—M. d'Haranguier de Quincerot substituted for the wooden foot-bridge one of iron, fastened to the trestles and joining them one to another when up, and falling with them when they are lowered, partially covering them when at rest on the floor. The

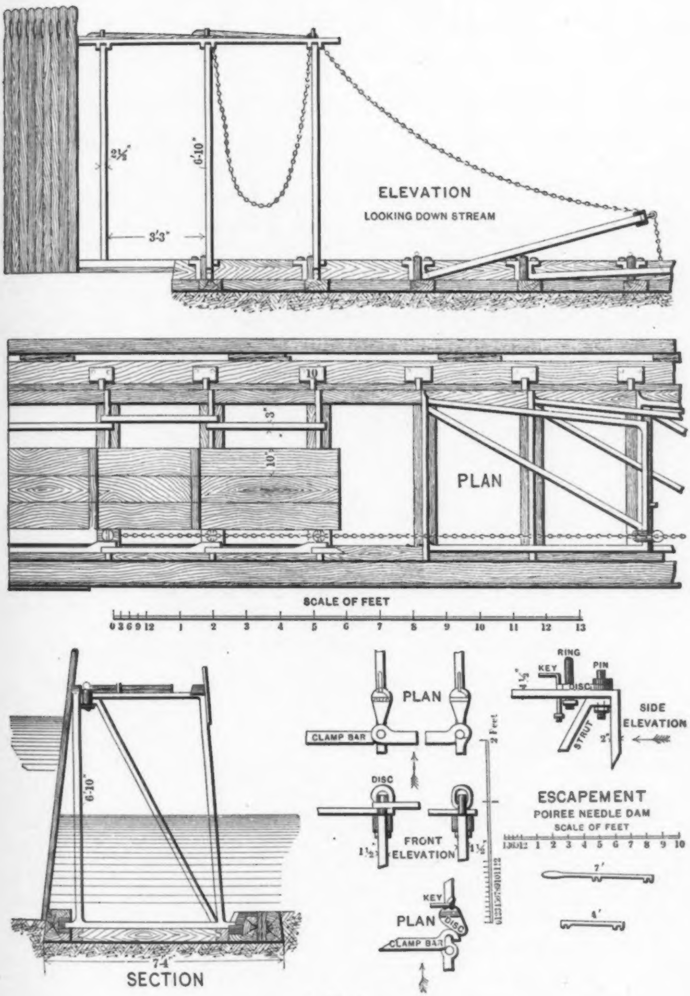
ELEVATION
LOOKING DOWN STREAM
2½"
6'10"
3'3"
PLAN
10
3"
10"
SCALE OF FEET
0 3 6 9 12 1 2 3 4 5 6 7 8 9 10 11 12 13
6'10"
7'4"
SECTION
PLAN
CLAMP BAR
DISC
FRONT
ELEVATION
1½"
2 Feet
KEY
PLAN
DISC
CLAMP BAR
RING
KEY
PIN
DISC
4½"
STRUT
2"
SIDE
ELEVATION
ESCAPEMENT
POIREE NEEDLE DAM
SCALE OF FEET
1 2 3 4 5 6 7 8 9 10
7'
4'

FIG. 1.

trestles of the dams on the Cher are thus arranged. They weigh 329 lbs., and are raised with a small winch. The adoption of the sheet-iron floor gives at one movement a solid service-bridge, when the trestles are raised, in addition to holding the trestles firmly together and supporting the heads of the needles. Other modifications soon followed that of the foot-bridge, and higher dams were built. Thus, from 1860 to 1869, in the dams built on the lower Seine, the trestles were made 10.82 ft. in height and placed 3.60 ft. apart. The introduction of high dams necessitated invention in another direction, *i. e.*, the releasing of the needles, which were greatly increased in size and weight. This device consists in connecting the trestles by a bar so made as to support the heads of the needles and capable of being released at one end by a simple arrangement, when the needles in that bay are allowed to fall.

Regulating Weir.—M. Poirée, the inventor of the needle dam, saw in the beginning the necessity of means being provided for the escape of surplus water so as not to overflow the needles and foot-bridge, and makes the following remark in this connection : * "The dam is accompanied by a fixed weir made level with the pool, the height of which it serves to regulate, while at the same time it affords a means of passing off any sudden rise which might happen to come at night or during the absence of the watchman."

The length of this dam is fixed by the width of the river at the point at which it is to be built, as it must be capable of passing the entire volume of water in the stream.

In the early history of movable dams these regulating weirs were all built stationary, but later inventions enabled them to be constructed of movable parts, the same as the passes or navigable portions, but not in the same manner. For this purpose the wickets of M. Chanoine, which will be fully described subsequently in this paper, have been largely used.

Needles.—The needles of the first dams were made of red pine, 0.13 ft. square and 8.2 ft. long, and weighed about 4½ lbs. when wet. Many later dams in France have needles 0.26 ft. square and 13.12 ft. long. On the later dams of the lower Seine the depth of water on the sills is 9.84 ft., and the length of the needles 14.76 ft. Much of this length must necessarily stand above water and is of use solely in the placing of the needles. Their construction varies with the locality,

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* De Lagrene, p. 179.

or the ideas of the engineer. Some are provided with a ring on the up-stream side through which a rope may be passed for the purpose of holding them when the dam is to be lowered; others are held to the bar connecting the trestles by a hook on the down-stream side, while in many dams they are plain scantling with a simple handle at the top. Their section also varies somewhat; some being square, some rectangular, while another form has a uniform width, but is larger at the point of greatest resistance than at either end. Hexagonal and semi-hexagonal needles, and needles with rubber up-stream facings on alternates, overlapping each of its fellows, have been proposed and experimented with, but none of these have come into general use. A hollow needle made of four planks nailed together and banded with iron has been proposed, and promises good results.

One serious drawback to needle dams has been the constant breakage of the needles when made of a size easily handled. This has been overcome in some dams by the introduction of a relieving bar placed at about one-third the height of the part under stress, and suspended by chains. This bar is of wood and rests against the up-stream sides of the trestles. Another method was proposed by the engineer Cadot when engaged upon the Saône improvement, which was to make trestles with two stages of needles, one above the other, but it is not known that this idea has had practical application.

The Chief Engineer of the large needle dams on the Marne has furnished the author the following, under date of May 29th, 1897, in regard to needle dams on that stream:

"The needles employed on the canalized portion of the Marne for closing the dams are of red northern fir, from 4 ins. to $4\frac{3}{4}$ ins. square, according to the lift, and of a length up to 16 ft. 5 ins. A needle of these dimensions reachés a weight of 100 lbs., and experience has shown that this ought not to be much exceeded. The placing and removal of a piece 16 ft. 5 ins. long, weighing more than 110 lbs., would require too great an effort on the part of the lock-tender or his assistants, and as the maneuver would become much more complicated and take a longer time, a part of the advantages of the system would be lost. This was the principal reason for giving up the needles which measured $7\frac{7}{8}$ ins. by $4\frac{3}{8}$ ins.; these were used for the purpose of experiment, but at this date they have been abandoned.

"Each needle is provided with a handle and an iron hook, which are considered indispensable for the operation. In placing a needle in position, it is held by the handle in an almost horizontal position, care being taken that the hook is around the support-bar; the end is

then allowed to enter the water and is carried around by the current till it is stopped by the sill. As the length of the needle from the hook to the end exceeds the length from the support-bar to the sill by $\frac{3}{8}$ in. to $\frac{3}{4}$ in., the foot of the needle scrapes along the floor just as the needle becomes upright. This takes away the shock from the support-bar almost completely, and assures the normal placing of the needle.

"The operation of removal is also carried out with the greatest ease. Usually a crab carried on a truck is used to raise the needle till it passes over the sill, when it swings on the support-bar and in the current. It is then lifted up by hand from the footway and loaded on to a car. A boat is only used in exceptional cases, and when the pools have reached the same level. To remove floating needles from the water, it is advantageous to use a crane with a collar at the end, in which turns a balanced beam with a chain or rope at each end; this crane is fixed to the car. The head of the needle is fastened to one of these chains and a pull is exerted on the other; the needle thus rises and is held by a man on the footway. In many cases the balance beam is used without having swung the needle, and the freeing and removal is thus accomplished at one and the same time. On some dams the car is replaced by a simple jointed lever, and the needles are then carried away by hand. Hook needles thus afford several combinations, for the suppression of all danger of operation (which is the real advantage of the system) is the object of such solutions."

Trestles.—The trestles were at first built of square iron and braced diagonally and horizontally with flat bars, but as the construction of higher dams became necessary, other forms of iron were used which had less weight for the same strength. However, bar iron is still used on some dams. The lower bar or base of the trestle terminates in journals which fit into cast-iron journal-boxes fastened to the masonry of the floor in which the trestle turns when lowering or raising the dam. The posts or uprights stand on this axle, and are fastened to it by means of plates of iron and rivets. A cap surmounts the posts and completes the trapezium. A brace reaches from the bottom of the down-stream post to the top of the up-stream one, and this is held in place by horizontal braces connecting the two posts. All members are united by riveted iron plates. A chain fastened to the top bar serves to lower or raise the trestle.

In order to raise the foot-bridge above danger of submersion, the trestle is sometimes surmounted by a rectangular framework of iron to which the floor of the bridge is attached, thus forming a safe connection between the trestles. The upper supporting bar of the

needles, when arranged for their simultaneous fall, is generally connected with the up-stream post of this frame.

Method of Working.—Originally the attendant and his assistant began at the abutment in the erection of the dam. The first trestle raised (which is the last lowered) is brought up by its chain or by a boat-hook. The clamp or hook attached to the trestle is placed in a ring fixed in the masonry of the abutment, and the planks of the foot-bridge laid. The trestle is then fastened to the coping by the front bar, which supports the upper end of the needles, and the back bars, joining the lower side of the trestles. They proceed in the same way with the remaining trestles, thus forming the skeleton of the dam. The needles are then placed one by one, first one space apart to break the force of the water, and, later, close together, to make as tight a wall as can be made. If it is desired to lower the dam, the needles are carried to the bank, one at a time, the bars and planks of the bay are removed, the hook which joins the last trestle to the last but one is then unfastened, and the trestle lowered by the chain, and so on until all are down.

More minutely, the following is a description of the operation of the Decize dam of the Loire River, in France. Suppose that part of the dam has already been raised, and that it is desired to raise the rest. The assistant carries to the next to the last bay three planks and the two bars which are to form the service-bridge and to hold up the trestle they are going to raise. The attendant, standing upon the bridge at the last bay, draws toward him the chain. A loop is passed through the chain which is attached to the trestle last raised and fastened to the head of the first trestle lowered. He attaches to a link of this chain with a hook another small chain 4.26 ft. long which he pulls tight at his convenience. Both men then move the trestle and raise it a little. Then the assistant draws it to an almost vertical position, while the keeper takes the handle-bar, and catches the upper side of the moving trestle between the projections on the end next to him to the last trestle raised. He then puts down the service planks, takes the holding-bar and attaches the trestle just raised to the one next to it by taking hold with the teeth of the bar those parts of the trestle heads above the cap through which the chain passes. He then detaches the handle-bar ready for the next move. The method of lowering the trestles is as follows: After the needles have been taken away

for a distance of say 60 ft., the dam-keeper joins the first and second trestles by the handle-bar, removes the holding-bar and the foot-bridge, which the assistant carries away, either to the bank or to a portion of the bridge not to be lowered. The keeper then draws up the chain to his feet, taking care that it is not kinked, seizes the handle-bar, removes it from the second trestle, and pushes the first one over, giving the handle-bar a twist which disengages it. The trestle then falls, dragging the chain after it. The dam-tender then draws the chain up to satisfy himself that the trestle is properly bedded, which he does by means of a ring in the chain fixed at a certain distance. In some dams the chains have been suppressed, and the raising requires several men and is done by a hook. On the navigable passes of the Saône, in which the trestles are 13.34 ft. high, the chains are fastened to the down-stream side, as there is less danger of catching. On these the foot-bridge is made of pine panels 0.13 ft. thick. Each one bears at its end on the consecutive trestles. The bridge is furnished with two side rails which carry an operating machine composed of a low wooden platform supported on an iron frame and running on four cast-iron rollers. This machine carries a ratchet windlass which serves to raise the trestles. An open-throated pulley is fastened to the end of the windlass rope and receives the draw-chain of the trestle. In moving, it rolls along the foot-bridge, raising the chain up so that it does not chafe the head of the trestles. This carriage can take fifteen panels with their bars, or it will carry enough needles to fill a space of 32 ft. It is operated as follows: Starting from the abutment, the first trestle is raised; for the succeeding ones it is brought down to the foot-bridge and rolls on the side rails. It is provided with hooks to hold it firmly in place. The dam-keeper takes in his hand a down-stream bar and the windlass pulley and walks to the end of the foot-bridge. He places the chain through the pulley and stands it on the bridge. An assistant at the carriage turns the windlass and raises the trestles. The dam-keeper catches the head with the bar which he has meantime fastened to the gudgeon of the last trestle raised, thus uniting the two trestles. He then takes the panel of the bridge, fitting the corner irons thereof around the corresponding gudgeons, and lets it down by a light hook. He then fastens the panel hooks and places the up-stream bar, when the bay is complete. The next trestle is raised in the same way, and the carriage is not removed until the load upon it is exhausted.

This operation is carried on quickly, easily and without danger. It also allows the trestles to be placed 3.83 ft. apart. The foot-bridge is clamped by hooks to the trestle head and restrained by notches cut in the ends of the corner irons. It is attached to the neighboring panel by forks, which form splices and ensure a continuous rolling surface for the carriage. The lowering of the trestles is accomplished in the opposite way. As there is considerable lateral stress on the trestles in raising them, U-irons have been found better than T-irons or cross-irons. The U-iron possesses a moment of inertia almost three times as great as the others, is easily rolled, and is well adapted to joining. The weight of one of the trestles of the Saône is 447 lbs., in the water, and the effort of traction necessary to commence raising the trestle is 356.4 lbs., which necessitates the use of a windlass. In the trestles at Port à l'Anglais the effort in raising is 1 045 lbs.

As to handling the needles there is usually no difficulty in carrying them by hand and no danger except at night or in bad weather. The density of red pine when wet is about 40 lbs. per cubic foot. The needles vary in weight from 4 to 103.5 lbs., and even the heaviest may be carried by the dam-keeper. However, the carriage before described is used to transport the heavier ones. To place a needle, set it horizontally on the bar along the line at which the needles touch the supporting bar when they are in position. Slightly incline the needle up stream, when the current will catch it and carry it to an upright position. On some dams a hook has been placed on the needles along this line which is fastened over the bar, and the needles carried into place with greater facility. Another method of placing is to take the needle and plunge it vertically into the water, allowing the foot to strike against the sill and the head against the supporting bar. The removal of the needle is done by hand by giving it a blow to raise its head from the supporting bar and then lifting it quickly.

The dam-keeper ought not to make an effort of more than 100 lbs. repeated several times. Fortunately, in the case of high lifts the level of the pool is very much lower before it is necessary to remove the needles. This is accomplished by the use of Chanoine or Des Fontaines wickets on the weir. If there are no devices such as these, it is necessary to resort to machinery to lift the needles. At the old Suresnes dam a windlass was employed on board a boat to remove all the needles, a cord being passed around the heads of all of them.

One end was fastened to the windlass on the boat, and on turning it the needles were lowered successively and the floating line drawn up to the boat; enough slack was left between two upright needles to enable the first one to be drawn away before the next one was started. This method also has the advantage of preserving the needles from accident. Release by escapements consists of unfastening the support bars of one or several bays and allowing the unsupported needles to be carried away by the current, where, having been fastened by a cord to a hawser, they are drawn to shore down stream. The escapement used in France allows the trestles to fall at the same time the needles are released, while the method used on the Meuse and in the United States allows the needles to be carried away, leaving the trestles and foot-bridge upright. There is no reason why the size of the needles may not be very much increased under this system, even beyond that at present attained on the Big Sandy River in America. It has, however, the disadvantage of a high foot-bridge and of scour at the foot of the pass.

The escapement method of releasing needles has found but little favor in France, while wholly used in Belgium, where the lift is somewhat greater. It is a valuable appliance, and where ice or drift is liable to accumulate against the needles, it should not be omitted.

History.—The development of the Poirée dam in France and Belgium since its invention will be the history of that dam. It has undergone some modifications. As the parts have increased in size, they have become complex and more difficult to handle. In the second dam, constructed at Decize, the connecting bars were found to expand in summer and to contract in winter, thus inclining the trestles considerably out of the perpendicular. To obviate this, two sets of bars were used, the shorter set in the summer season. An improvement was made in the journal boxes by which trestles could be more easily put in when repairs were necessary.

In the first dam, erected at Basseville, the trestles were 6.56 ft. apart, but this number was soon doubled; they were 4.92 ft. high and 3.28 ft. wide at the base. They operated with perfect success. The Decize dam, built in 1836, was 328 ft. long. The trestles were 6.23 ft. high, 3.28 ft. apart. In the Epineau dam, in the Yonne, erected in 1837, the trestles were 6.58 ft. high and 3.28 ft. apart; the sill being 1.28 ft. below low-water mark. The fixed weir was 403 ft. long, the

pass being 229.6 ft. long. The Marne dam (1841) was 6.69 ft. high as to the trestles. The sill was 2.62 ft. below low water, the weir was 1 410 ft. long, and the pass 158.42 ft. long. The Yonne dams, erected from 1838 to 1842, had trestles from 7.5 to 7.38 ft. high. The Courbeton Dam (1849), had a pass 123 ft. wide. The trestles were 8.03 ft. high and weighed 371 lbs. each. This upward tendency in the height of trestles has constantly gone on until a height of 13.12 ft. was reached in the Meuse dams, and 15.2 ft. in the United States.

Conclusions.—S. Janicki, engineer of the Moskva River, says that experience has proven the total lack of basis of the original predictions made by engineers that Poirée dams would be dangerous and unsatisfactory for many reasons. Nowhere have the sills been covered with sand; nowhere has the bed of the river been raised. It must not be forgotten that these dams are laid down so as to leave a free passage for high water. Their whole value is contained in these words. These dams are not erected until after the alluvium held in suspension has practically been carried away and the water has become clear. The velocity of the stream in high water is sufficient to carry away all such substances.

The following are the words of the Russian engineer, Lieutenant-Colonel Palabine:*

"As for the Poirée system of movable dams, a system quite well known among us, both by the descriptions of it which we have and by some application already existing, we must confess that it is one of the happiest inventions of our century, rich as it is in wonderful inventions. Indeed it is quite difficult, especially after the well-known improvements it has received in the past few years, to better fulfill the manifold requirements for an artificial navigation by means of dams in rivers of variable levels. And it is particularly on our rivers, whose banks are generally scantily wooded, that this system is destined to give remarkable results. Most of the rivers of western Europe are fed by constant springs from vast plains; ours, on the contrary, draw these waters from vast plains mostly destitute of forests. We, therefore, see them almost run dry during the droughts of summer, and become swollen after heavy rains. Again, the thick bed of ice with which they are covered in winter, gives rise to phenomena almost unknown on the rivers of western Europe. Inundations many miles in width occur, and also formidable ice floods which destroy every would-be permanent construction in the bed of the river. In France the Poirée movable dams are universally ap-

* *Journal of the Central Administration of Transportation Routes and Public Buildings*, Vol. xii, page 21.

proved, and are there in general use for the canalization of rivers. Here, in Russia, their inauguration on the canal from the Dneiper to the Boug made an epoch in the history of the improvement of our river navigation, a navigation of the greatest importance for the economical welfare of our country, whose vast system of rivers is in a great measure destitute of water during the summer season."

In Vol. XV, 1868, Annales des Ponts et Chaussées, M. Saint Yves, Ingénieur des Ponts et Chaussées, says in reference to the Poirée Dam:

"At the Martot dam the trestles are 11 ft. high. The first needle dams were joined to permanent dams raised to the level of the upper pool and regulating it; as the lift was increased this became impracticable and the regulation of the pool was accomplished by spacing the needles. There is no excessive labor required of the dam-tender and his assistant. They can carry two needles at a time, each weighing not to exceed 35 lbs. The placing of the needles is neither difficult nor dangerous. The needle seldom misses the lower sill and when it does the attendant will not be carried overboard if he lowers his hand. Removing the needles requires skill which is easily acquired. Maneuvers from a bridge are less dangerous than from a boat. The bridge is 3 ft. wide and firmly held in place by claws. Night work is not often required. The partial opening of the dam has never yet prevented a boat from entering the lock. The dam is usually placed at the lower end of the lock. There is less danger from scour than in any other dam for the reason that there is no overfall. Scour is to be dreaded only in flood times. Since chains have been taken off the trestles they can be bedded easily by two men and lie flat in the recess. The sill has been raised to 14 ins. above the recess. As to the charge of unhealthfulness, this might be said of any dam whatever with equal truth. In fact the needle dam is less objectionable on this account than any other, as the removal of a few needles will allow floating bodies to pass through. He considers the Poirée needle dam the most perfect for all-around purposes yet invented. Every movable dam ought to form a connected body of supports designed to sustain a face for the dam, which should be as tight as possible, and which is placed at right angles to the current. The axes of rotation should be at the bottom of the river and should be across the current rather than with or against it. The Poirée trestles are therefore logically conceived and are also a natural support for the bridge. In systems whose axes of rotation are at right angles with the current the foot-bridge idea is entirely lacking, and this must be an independent construction. The Poirée needles were as small as possible in order to reduce the labor of maneuvering. The pressure is in direct ratio to the surface of the needle. It is in accord with the enlightened judgment and perspicacity which characterize M. Poirée's system that the dimensions of the needles were reduced as much as possible."

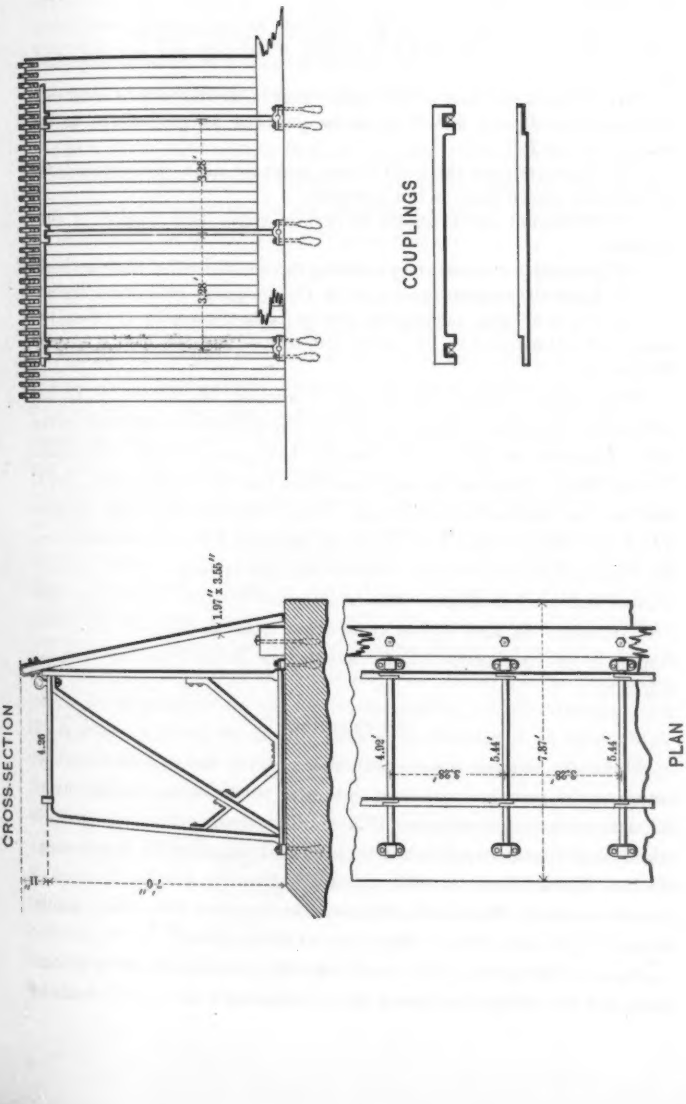
COUPLINGS
3.28'
3.28'
CROSS-SECTION
4.26
1.97" x 3.55"
7'0"
PLAN
4.92'
5.44'
7.87'
5.44'
3.28'
3.28'

FIG. 2.

M. de Lagrene, formerly of the French Corps of Engineers, sums up the following objections to needle dams:

"1. Difficulty in placing and removing needles when the trestles are higher than 8 ft.

"2. Danger to the men obliged to work on the narrow foot-bridge, which danger increases with the weight of needles and the difference of level.

"3. Scour at the foot of the pass; that is, at the foot of a delicate and costly work and which is to be dreaded in proportion to the amount of the fall.

"4. Currents near the head of the locks or near the channels for navigation, where there is but one pass.

"5. Continual watchfulness at certain times and danger of submersion.

"6. Difficulty of accurately bedding the trestles when they are high.

"7. Unhealthfulness produced by the stoppage of floating bodies.

"8. If a long and permanent weir is connected with the dam the danger of submersion or of scour diminishes, but the cost is greatly increased."

Needle Dam in Brazil.—M. de Teive e Argollo, M. Am. Soc. C. E., has furnished the author a drawing and description of a needle-dam in the river Piabanha at Petropolis, Brazil, belonging to the Cascatinha Cotton Mills. This dam closely resembles the first Poirée dams built, but has one distinct improvement. This is the handles of the needles, which are straps of iron bent over the heads and bolted through from the upper to the lower side. The trestles are spaced 3.28 ft. between centers and are 7 ft. high. The needles are 1.97 ins. by 3.55 ins. and 7.87 ft. long. It also differs from other dams in that the sill is not sloped to fit the incline of the needle, the latter touching it at the top only.

In Belgium.

There are twenty-seven needle dams on the Belgian Meuse which comprise the principal improvements and modifications made, up to the date of their construction, 1875–8. The description here given is taken from a memoir published by the chief engineer of the system, the late Martial Hans, in 1880, entitled "*Mémoire sur les Travaux de Canalisation de la Meuse entre Namur et la Frontière Française,*" kindly furnished the author by J. Hans, son of the engineer.

General Description.—The works include a lock and a movable dam composed of a navigation pass and weir separated by a pier. Some of

the dams are located above the lock and are connected with it by a paved dike, while others join directly to the lock wall. The locks are 410 ft. long from out to out and have a clear width of 39.33 ft. and an available length of 328 ft. The depth of water on the lower miter sill is 6.9 ft. The upper and lower sills are on the same level. The navigable pass consists of a floor of masonry and concrete, surmounted by iron trestles and wooden needles, and is 150 ft. in length. Its sill is placed 2 ft. below low water, generally. The weir is 179 ft. long and has its sill 2 ft. higher than that of the pass. The floor is of masonry and concrete, and supports wickets maneuvered from a foot-bridge. When up these works produce a pool 10.17 ft. above the pass sill.

In those dams situated above the lock and connected therewith by an earth and gravel dike, paved all over with stone, there is at the end of the pass an abutment of masonry and concrete. It is 25½ ft. long and 16½ ft. wide and stands 13½ ft. above the sill.

Trestles.—Trestles, movable around a lower axle parallel to the current, and placed 3.93 ft. center to center and standing 11.48 ft. high from the floor to the under side of the collar of the movable bar, constitute the framework of the pass. They are 8.36 ft. wide at the base and 4.76 ft. at the top. The frame thus formed is of welded wrought-iron bars, a double brace of the same kind of iron held in the frame by horizontal binding pieces and reaching from the bottom of the down-stream post to the top of the up-stream post, serving to make it rigid. This brace is held at the bottom by a piece of thin iron bent around the axle and bolted at the top by two recessed and swelled connections firmly joined by means of a quoin fitting between the cap of the trestle and the top of the brace and fastened by a bolt. The frame proper is surmounted on the up-stream side by a hollow tube and on the down-stream side by an iron post, each of which is 19.70 ins. high and is attached to the trestle. The axle which supports the floor of the service-bridge connects these uprights, thus raising its height to 13.12 ft. above the masonry and 19.70 ins. above the water in the upper pool. The weight of the trestle as just described, without floor, or escape bar, or chains, is 800 lbs.; the floor weighs 200 lbs. and the bar 66 lbs. The total weight including chains is 1,108 lbs. Journal-boxes, in which the axle of the trestle turns, are fastened to the floor, the one up stream being let into the sill, and held by screws and bands, and the one down stream being bolted to the stone. They

weigh 70 and 200 lbs. respectively. The lower box is opened and flared upwards to allow the easy introduction of the journal, and closed on the down-stream side by a vertical back which receives the shock of the trestle and prevents the latter from yielding to the force of the water. A flat key inserted in transversal openings made in the cheeks of the box holds the journal to its place, and this key can be placed without the aid of a diver.

A sheet-iron floor connects the trestles and holds them rigidly together, revolving around a small axle at one end, and at the other terminating in two double claws, flared in the shape of a deer's foot, which grasp the cap of the next trestle, and are held in position by two small keys. The floor is 3.60 ft. wide. Connections are made with the pier and abutment, or lock-wall, by bars similar to the cap pieces fastened in the masonry. Maneuvers of the trestles are made as follows: When it is desired to lower them it is sufficient to lift the floor (after having removed the keys) and push them toward the pier, when the trestle will fall gently upon the masonry below, its motions being retarded by the action of the water upon the sheet-iron floor. The raising of the trestle is done by the help of a portable winch; to facilitate this maneuver all the trestles are connected by chains of suitable lengths which are made fast to the ends of each piece of floor, and which may be attached by means of a ring and toggle to the middle of the cap of the preceding trestle. The operation of raising is begun at the lock or abutment end, the winch being first fastened to the masonry to bring up the first trestle. When this one is in place, and the floor properly attached to the masonry, the winch is moved to it, and the second trestle is raised, its chain having been brought to the surface by the first one; the operation is repeated, the foot of the winch-frame resting on the cap of the one that precedes it, until all the trestles are in place.

The chains used for raising the trestle are divided into two parts, one of which is fastened to a trestle and the other to the floor of the adjoining trestle. When the trestles are to be lowered, these parts are united. They are separated when the trestles are standing, as they would otherwise interfere with the escapement of the needles and the turning of the clamp-bars. The escapement device (invented by M. Kummer in 1845) is described as follows: At the top of each trestle, just above pool level, is an iron bar, movable around a vertical axis

formed by a tube welded on the trestle very nearly in the prolongation of the upper post; the other end of this bar rests against a vertical rest-post (*poteau-valet*) placed inside of the tube of the preceding trestle; when in this position the movable bar forms the upper support of the needles whose lower support is obtained from the projection of the sill above the floor.

The rest-post, against which the free end of the movable bar is supported, is cylindrical for the whole height of the tube in which it is enclosed, except in the part that corresponds to the end of the movable bar; this part is notched and has the form of a half-cylinder. The tube also is notched so as to leave a free passage for the end of the bar of the preceding trestle, and the same thing, for the same reason, is true of the rear end of the collar of each movable bar.

The head of the rest-post, which projects above the tube, is square, and is turned by a wrench when it is desired to let the needles go. The movement in azimuth is limited to a quadrant by a set-screw which travels in a slot cut in the tube. This screw prevents vertical movement of the post also. The movable bar is provided with a projection on its lower side which strikes the trestle, and limits its rotation to 90 degrees.

Tests of iron for the trestles developed the fact that a rectangular cross-section is the best. Channel and T-irons were put together in various ways, but showed less strength. Those selected sustained a force of 17 638 lbs. applied at the base of the tube, and this without springing the frame permanently out of shape. The maximum normal strain on the trestle is 4 409 lbs.

Needles.—The needles are made from red Riga fir. They are 12.3 ft. long and $3\frac{7}{8}$ ins. uniform width. They are $4\frac{3}{4}$ ins. thick at the point of maximum pressure, and 10 ins. each way therefrom. They are $3\frac{7}{8}$ ins. at the bottom and $3\frac{1}{2}$ ins. at the top. The head of the needle or handle is 9 ins. long, ending in a ball with a view to handling. It is provided with an eye, through which passes the maneuvering rope which holds all the eleven needles of the bay. These eleven needles form a set or series. A knot in one end of the rope holds it in the eye of the first needle. The other end is tied to the down-stream leg of the trestle. The needles weigh each 55 lbs. and withstand a test three times as great as that to which they are subjected in the dams of maximum lift.

When it is desired to remove the needles the rope of any series is attached to a main hawser which is tied at one end to the pier or shore, then the Kummer escapement is turned, allowing the needles of the series to escape. They are carried below the dam and prevented from floating away by the rope.

The needles are placed by hand. The dam-tender grasps the needle by the head, slides it horizontally to the proper position, and allows it to strike the current, which carries it into place against the sill and clamp bar.

Wickets.—Chanoine wickets are used on the weir. There is a trestle foot-bridge above the wickets from which the latter are raised and lowered and the height of the pool regulated. There are thirty-nine wickets 7 ft. 4 ins. high by 4 ft. 3 ins. wide. The space between consecutive wickets is 4 ins. It may be closed by a board in low water. When up, the tops of the wickets reach the level of the upper pool.

The horse supporting the wickets is quadrangular in shape and made of wrought iron. The upper and lower cross-pieces extend beyond the uprights, terminating in journals. The lower ones work in cast-iron boxes on the sill, and the upper ones in wrought-iron boxes which are bolted to the upright timbers of the wickets at a point slightly above the lower third. The cap of the horse has two wrought-iron flanges through which runs a bolt which joins the prop to the horse. The wicket has two axes of rotation, one at the top, the other at the bottom of the horse. The prop rests against a cast-iron hurter when the wicket is raised. When the prop is removed from its support, the pressure of water against the wicket forces it to fall. It lies flat and is held a few inches from the floor by projections therein, and by the prop and boxes, in order to allow the tripping bar to work under it.

The wickets in the Meuse are provided with flutter valves or *vannes-papillon.* They are set in the central portion of the chase, and when open they form an angle of 45° with the wickets. The purpose of these valves is the easier regulation of the pool.

The weir is lowered by an iron tripping bar, provided with projections. These projections strike the props of the wickets transversely in succession, forcing them aside from the hurters. The tripping bar is operated by a capstan in a well in the pier or abutment. The

end of the bar is provided with a rack into which the pinion of the gearing works.

The wickets are raised from the floor by a portable windlass set on the foot-bridge. A chain attached to the breach of the wicket is wrapped around the windlass, turning the wicket around its axis until the prop drops into the hurter (see "Chanoine Wickets," for more elaborate description of the foregoing).

The wicket when upright is permitted to swing 21° around the upper axis. When the water rises 6 ins. above the normal level of the pool, the wickets swing. They remain on the swing until the pool falls sufficiently to allow them to right themselves or until pulled into place by the hooks of the dam-tender—an easy accomplishment. To prevent the accumulation of gravel and sediment in the tripping-bar well, a flushing apparatus for running water from the upper pool into the well has been devised. It consists of a 4-in. pipe built into the masonry, provided at the top with a valve, and at the bottom with an elbow. A grooved collar permits the elbow to revolve 90° and to reach all parts of the machinery with a stream whose velocity forces the débris out of the well.

Maneuvers.—To raise the dam after spring rise: The trestles of the pass are first raised when the water has reached its normal level or about 8 ft. 2 ins. above low water. Next, the trestles of the weir are raised by a windlass. The wickets of the weir are now raised, and kept on the swing by fastening each chase chain to its trestle. As the river falls, needles are inserted sufficient to maintain the normal level of the upper pool, until the whole dam is closed. The discharge now overflows the weir; the wickets still being on the swing. As the stream falls, the wickets begin to right themselves spontaneously, and, later, the dam-tender pulls the balance into place with his boat-hook.

The flutter valves still remain open, and as the discharge becomes less, these are closed by a pike pole. Finally, the joints of wickets and needles are covered; reducing leakage to a minimum.

The regulation of the pool is done by the flutter valves during low water. When freshets run out, the wickets swing by pressure of water on the chase. The freshet continues until all the wickets swing; sets of needles are allowed to escape sufficient to keep the pool at or near its normal level. The bays are removed in systematic alternation, to prevent scour.

When the lower pool rises to within 16 ins. of the upper, all the escapements are turned. The trestles are let down, and the wickets are lowered with the tripping bar. Last of all the trestles of the pass are let down.

Results.—All wicket dams must be lowered sooner and raised later than those of the Meuse model. Thus the dams at Hun and Houx on the Meuse were lowered twice between April 17th, 1877. and Nov. 5th, 1878, and they remained down seventeen days in all. The all-wicket dams at La Plante, Tailfer and Rivière on the Meuse in the same period were lowered five times and were down one hundred and sixteen days. The former is also a tighter dam.

The cost per running foot will average about $100 for the fixed and $40 for the movable parts for the pass, and $70 for the fixed part and $75 for the movable parts of the weir.

Escapements.—The most important improvement so far made in needle dams in Europe is, without doubt, the application to the trestles of the method of escapement of needles invented by M. Kummer, at that time Chief Engineer of the Meuse Improvement in the Province of Liege. It has worked with great satisfaction for over fifty years. By the use of this invention alone has it become possible to employ needle dams of high lift abroad, as it will always be easy, whatever the lift or the length of the needles, to open the dam; for, by this system, it is the pressure of the water in the upper pool which makes the needles fall, and carries them below the dam.

M. Hans says in this connection that, "although the new dams in actual use, or in process of construction on the Meuse, above the village of Rivière, create pools with depths of 10.17 ft. on the sills of the navigable passes, which is more than is obtained by any needle dam in France, we are convinced that we have not reached the limit at which these dams will cease to work properly and easily, providing always that the trestles be supplied with the Kummer escapement."

Increase in Lift.—In a letter to M. Malézieux, dated September 30th, 1876, the same engineer has the following remarks to make:

"You do me the honor to ask if I am convinced that a man, suitably chosen and exercised, could carry and place in position needles suitable for a pool of 13.12 ft. above the sill.

"I can answer this question in the affirmative. This answer results from the experience acquired in maneuvering our high-lift trestle dams. These dams have, as you know, an actual lift of 10.5 ft., and yet the needles of these dams are carried and placed in position with

such a facility that I am convinced that their dimensions could be notably increased without departing from practical conditions.

"I will add that needles for a pool 13.12 ft. have long been in use in your country at the old dam of Pontoise. In fact, the following is from a report of Chief Engineer Kummer on his investigation in 1845:

"'The Pontoise dam consists of (1st), a pass 41 ft. wide; (2d) an oblique, fixed part 262.4 ft. long, reaching to the right-hand wall of the pass; and (3d) another fixed part more up stream, and on the right of an island. The pass walls are 17.22 ft. high. The floor at the upper end has a recess 4.75 ft. deep. A service-bridge of two beams connected by iron straps, 3.93 ft. wide, rests on a sill fitted into recesses made in the face of the walls. This sill is 4.1 ft. below the crest of the walls and 13.12 ft. above the floor, a height which corresponds with the height of an average rise in the Oise. Needles serving to close the opening rest against the up-stream edge of the service-bridge and the lower recess in the floor. These needles are 14.76 ft. long and 4.75 ins. square. In the upper part of each needle is a hole. In order to disengage a needle from its points of support, the lock-keeper inserts a lever in this hole, and, pressing it down on a block of wood which he has placed on the service-bridge, he raises the needle until it is released from the lower recess and is carried off by the current. But, as the head of the needle is retained by a rope, it is brought back up stream and is there fixed. The opening is thus carried out, needle by needle. The closing is done by hand. The lock-keeper employed in December, 1845, was one-armed, and, nevertheless, he made the opening in 25 minutes, as regards the raising of the needles, and the closing in one hour. This dam has worked perfectly for nine years. The needles of the Pontoise dam should weigh about 92 lbs. If the pool of 13.12 ft. had no counter-pressure down stream, the needles of this dam would be strained a little more than those $3\frac{1}{7}$ ins. square used in the dam at Martot for a pool of 9.84 ft. This strain is exaggerated even for a first-rate pine, and in such a case it would be expedient to increase the section of the needles.'

"If I had to build a needle dam, with a 13.12-ft. pool and no down-stream pressure, I would give the needles a shape of uniform strength similar to that I used for needles in the dams of Hun and Houx. These needles would be 15.25 ft. over all, including the handle; $4\frac{5}{8}$ ins. wide throughout, and $4\frac{29}{32}$ ins. thick for a distance of 10 or 12 ins. each side of the point of greatest pressure. This thickness would be reduced to $3\frac{29}{32}$ ins., or even $3\frac{1}{2}$ ins., towards the two ends of the needles. The weight of such a needle would be about 90 lbs., and would be lighter than those that the one-armed lock-keeper at Pontoise handled with ease.

"I should add that in a river like the Meuse I would propose the use of needle dams with 13.12-ft. pools, only on condition that there should

be added a wicket weir of sufficient length (spillway) to regulate the pool in ordinary conditions without making it necessary to maneuver the needles too frequently. Without this condition I should fear that a needle dam of this height would not be tight. The trestles, also, should be fitted with the Kummer escapements, for I do not think it possible by any other means to take out quickly enough needles 4⅝ ins. wide which take the pressure from a 13.12-ft. pool.

"But I am persuaded that, with the use of a regulating wicket-weir of suitable length and of trestles with Kummer escapements, we can avoid, even with a 13.12-ft. pool, all the drawbacks generally cited against needle dams, and especially the fault of leaking. In practice the dam at Hun has a pool of 10.43 ft., with a down-stream pressure of from 1.96 to 2.30 ft., and the screen of needles of this dam is rendered perfectly tight by grass or weeds and a thin coating of mud, which the water has brought down."

In the United States.

On Big Sandy River.—The original purpose of this paper was to describe the new needle dam at Louisa, Ky., on the Big Sandy River. In order to compare it with dams of this type abroad, it was necessary to touch upon the Poirée needle dams of France, where they originated and have been extensively built, and of Belgium, where they have been considerably modified and applied to greater lifts. A comparison with its principal competitor, the Chanoine wicket, then seemed desirable, so that the scope of the article widened as it advanced. After this much had been done, it did not seem fair to omit mention of other types of movable dams in use, and, finally, it was decided to briefly take up all forms applied or proposed, so far as known; but the chief object of the paper—the description of the first American needle dam—has not been lost sight of, and it will now be described at considerable length.

This dam was completed and opened for public use January 1st, 1897, and has been in successful operation throughout the past year. Its design is a radical departure from those of Europe in many particulars. The needles are very much wider and heavier, the style of trestle much lighter, and its construction much cheaper, and the methods of operation of both trestles and needles are entirely new. The head of water sustained considerably exceeds that of any movable dam of the trestle or wicket type known to the author. Many new features of minor importance were introduced in the design, most of which were for the purpose of simplifying the maneuvers.

The plans of the lock were prepared under the direction of the late Colonel William E. Merrill and Major James W. Cuyler; the lock masonry and part of the stationary dam were built under direction of the late Major James C. Post; the original project for a movable dam was decided upon by a board of engineer officers, consisting of Colonel William P. Craighill, Past-President Am. Soc. C. E.; Major D. W. Lockwood and the late Captain Thomas Turtle, and the plans were prepared and the substructure built under the direction of Major Lockwood. Later, a board of officers, composed of Colonel Amos Stickney, Major James F. Gregory (since deceased), Major D. W. Lockwood, Captain Hiram M. Chittenden, and Lieutenants W. E. Craighill and William W. Harts, Assoc. M. Am. Soc. C. E., reported upon certain modifications in the plans, which seemed advisable, and new plans for the superstructure were prepared and executed under the direction of the late Major James F. Gregory. The author has been in local supervision of the work since its inception. In the preparation of the drawings, calculations and translations of French works upon the subject, as well as in the construction itself, the author desires to acknowledge himself greatly indebted to Messrs. J. M. G. Watt and D. A. Watt, assistant engineers.

The description following is substantially a report* of the author to the engineer officer in charge, made after the works were completed, with such omissions and additions as seemed advisable, and, while it is quite long, yet it is not seen where anything can be omitted and still convey a complete idea of the construction of the works.

It is probably not out of place to state that the author recommended a needle dam for the pass, and wickets for the weir, and that a majority of the last board reported favorably upon this combination. As the first board had recommended needles for the entire dam and two members of the last board were in favor of the idea, the Chief of Engineers, General Craighill, who had been a member of the first board, and who had given the matter much thought and had investigated the subject of movable dams thoroughly, having been in charge of those on the Great Kanawha for many years, decided upon needles for both pass and weir.

There was no precedent for this, but neither was there for the lift adopted, and if the engineers of this country wait for a precedent, it

* Report of the Chief of Engineers, United States Army, 1897, p. 2534.

is probable that movable dams will continue to be applied, as they have been for fifty years, only to small heads.

Location.—The lock and needle dam which have recently been completed and put into operation on the Big Sandy River, near Louisa, Ky., are situated just below the junction of the Levisa and Tug Rivers, which, uniting at this point, form the Big Sandy, which empties into the Ohio 26 miles north of the junction. The Levisa is navigable by steamboats during a good part of the year for a distance of 100 miles, and the Tug for 60 miles. Beyond these points (and all along these streams during low water) push-boat navigation is usually carried on, so that it may be said that there is generally a means of transportation for local freights throughout the year, except in periods of extreme low water, which are usually of short duration.

Character of River.—These two streams with their various tributaries traverse a mountainous territory, the soil of which is greatly impregnated with sand, which conditions are favorable to frequent and sudden freshets carrying large quantities of sediment and débris, which often become a source of trouble and danger to navigation, particularly on the Big Sandy itself, where the backwater from the Ohio reduces the velocity of the current, and causes the formation of sandbars and snags. The steep slope and the porous nature of the soil are unfavorable to the retention of water for the dry season, and the low-water discharge becomes quite small. The system of regulation and maintenance by which these streams are made navigable for a portion of the time, is insufficient for the increasing demands of commerce, and it is only by canalization that they can be rendered even fairly satisfactory, and even then evaporation and leakage may partially defeat the objects in view.

Conditions to be Satisfied.—The greater portion of the present commerce is timber, either in rafts, crossties, staves or spokes. There is a large undeveloped coal field which it is expected will greatly increase the river trade, and the principal object of the improvement instituted by the construction of this dam, is for the transportation of this coal to the Ohio, where it can find a market. In determining the character of dam to be built it was necessary to consider the present and prospective demands of this commerce. To construct a stationary dam would make it imperative for everything to pass through the lock. This would be most injurious to the timber interests. There are

times when rafting tides are infrequent, and hundreds of rafts are awaiting sufficient water to reach the Ohio. Even when the long delayed rise comes, it may be of short duration. In such cases a delay of a few days at the lock might mean the failure to reach the markets along the Ohio and Mississippi during a whole season. The same argument applies to the transportation of coal in barges. The formation of a pool will give ample depth of water in which to load the coal as fast as mined, and a safe harbor for holding the barges. It is then ready to go out to the Ohio whenever there is the necessary depth below the dam. There are many summer rises wherein this depth only lasts a short time, and should it be necessary to pass the barges through the lock, the delay in so doing might sometimes prevent their shipment as well as retard rafts awaiting lockage. Another difficulty to be overcome was the accumulation of sand in the quiet water of the pool. Should bars form at points where the depth of water was already barely sufficient for the requirements of navigation, the improvement would be worse than useless. The great amount of drift afloat on every side also rendered it probable that snags would readily form in the pool and endanger the safety of navigation.

Original Plan of Improvement.—The original project was for a masonry lock with a fixed dam made of timber cribs filled with stone, such as are built on many small rivers. The project and the causes leading to its adoption are thus given by Major Wm. E. Merrill, Corps of Engineers, U. S. A.*

"A great deal of good to the rafting interests can be done by a continuance of the present method of improvement, but no radical improvement is possible without the construction of locks and dams. The large deposits of excellent coal on this river will undoubtedly at some day lead to the establishment of a system of slack water in order to bring it to market.

"The amount of shifting sand that continually flows down the Big Sandy indicates beyond all doubt that the only way to secure a permanent improvement is by the construction of movable dams, commencing at the mouth and extending upwards to points where the moving sands have become manageable. If permanent dams are built in the lower river, the sand deposits will ultimately reduce the depths available for navigation, but with a succession of such dams there will be such a reduction of slope in the pools as will, in spite of the sands, maintain in the channel a greater depth than is now found in the natural river during the season of low water. In other words, per-

* Report of the Chief of Engineers, 1879, p. 1354.

manent dams will notably improve navigation when first built, and this improvement will gradually diminish, but the ultimate depth for navigation will always be greater than it is now, and to this extent the improvement will be permanent.

"If movable dams are built, all danger from deposits of sand is removed, because the river will be as free during all stages of over 6 ft. as it is now, and the sands will be washed down stream just as they are now. The only objection to the immediate construction of movable dams is that they are much more costly per foot lift than fixed dams. The greatest lift from pool to pool at present (1879) practicable with a movable dam is 6 ft., while 10 or even 12 ft. is not excessive with a fixed dam.

"The method which I would recommend, in view of all the circumstances connected with this river, is to build a series of fixed timber dams with masonry locks, with a view of ultimately turning the fixed dams into movable ones.

"To accomplish this I would take 12 ft. as the lift of each fixed dam. This would make it necessary when these dams were made movable, to interpolate a new movable dam between each pair of transformed dams. If this system were carried out, when it became necessary to make the changes we would only lose the cost of the timber dams, as the masonry locks would be used in connection with the movable dams. The total cost of the system would be only slightly increased, and we would have the advantage of the immediate use of the cheaper system, and the additional advantage of testing by actual experience whether or not fixed dams would answer, or which of them would answer and which would not.

"The special commerce on the Big Sandy that now needs assistance is coal mining, an interest that fully deserves national aid, as the whole country along the Ohio and Mississippi is interested in having cheap and reliable supplies of coal. The present greatest drawback to coal mining on the Big Sandy is the lack of any pool of deep water in which loaded barges can be stored during low water. The first work, therefore, that should be undertaken is the creation of a pool that will be a benefit to the mining interests, and to as many others as can be accommodated.

"It is evident that the proper place for this dam is just below the junction of the two forks of the Big Sandy and in the vicinity of the town of Louisa."

Work under this project was begun in 1883 and carried forward at intervals under various small appropriations for several seasons, resulting in the completion of the lock, abutment and part of the fixed dam, when, in 1891, the project for a fixed dam was abandoned and that for a movable dam substituted.*

* Report of Chief of Engineers, 1892, p. 2102.

Modified Plan of Improvement.—It was these special and difficult conditions which in the first place caused the project for a stationary dam to be abandoned, and in the second place led to the modifications in the plans of the movable dam after considerable progress had been made on its construction. The result is that the works as finally completed do not present that unity of appearance which should be expected of a structure built on original plans, and the cost has been greatly increased by the numerous alterations and delays.

The plan of improvement as finally agreed upon was a lock of the ordinary pattern and a movable dam with a navigable pass having 13 ft. on its sill and a weir having 7 ft., both closed by needles supported against trestles.

Choice of a System of Movable Dams.—In choosing a system of movable dams which would most nearly satisfy all the conditions found upon this river, a study was made of existing works of like character in this country and abroad. The navigable rivers of France, with a single exception, the Rhône, are improved with movable dams, several systems being in use. The needle dam of Poirée and the wicket of Chanoine are the two principal types, however, but the Desfontaines drum-wicket, the Girard hydraulic shutter, the Boulé gate and the Cameré curtain are all in use, as is also a type known as the overhead bridge dam in which all the supports, when not in use, are pulled up to a bridge spanning the stream. In this form of dam, curtains are used for holding back the water, although other means of closing may be used.

In Belgium the needle dam is in favor, and has been greatly improved over those in France. In Russia, quite an extended application of the Boulé gate has been made, and needle dams are also much liked. In Prussia, the overhead-bridge dam, with gates instead of curtains for closing, has been applied. In Germany, there are some drum-wickets of great size in use. In the United States, there was but one type, the Chanoine wicket, either in the original form or as modified by M. Pasqueau at the La Mulatière dam in France. The bear-trap, the pioneer movable dam, and an American invention, has been neglected so long or tried under such unfavorable conditions, that it was scarcely mentioned in the discussions of movable dams a few years ago, although it is capable, at least with a little assistance from another type, of being made successful on streams as small as the Big Sandy, and probably

for those of much greater width. In addition to the types mentioned, several other forms have been designed and suggested. Some of these have elements of promise; but as they have had no practical application, they were not seriously considered in the study. In deciding between the systems proposed or in use, the following points are to be considered for a dam at this point:

(1) The unprecedented lift sustained (except on bridge dams).

(2) The sudden and unexpected rises.

(3) The great amount of drift carried.

(4) The unusual quantity of sediment traveling.

(5) The great difference in level between high and low water.

(6) The small low-water discharge.

The high lift was considered unfavorable to the use of needles; the sudden freshets to any form requiring much time for maneuvers, like the Boulé gates or Cameré curtains with trestles; the drift and sediment to any system having trestles; the height of high water and the banks to bridge dams and the small discharge of the river to wicket-dams of the Chanoine type.

Bridge dams and gates and curtains being considered impracticable for this location, at least as constructed abroad, and the bear-traps not being looked upon with favor for a river where any dam is considered more or less an experiment, the choice was narrowed down to the Chanoine wicket or Poirée needle, and it was finally decided to build a needle dam sustaining a considerably greater head than that which had been attained in the high needle dams on the Belgian Meuse or elsewhere, so far as known.

Composition of Works.—With the foregoing general remarks upon the location, conditions, plans and projects, a more complete description of the details of the various parts of the works will now be given.

The works as constructed comprise the following:

A lock in the right or West Virginia bank, 52 ft. wide, 255 ft. long over all; a navigation pass, next the lock, 130 ft. long; a weir, 140 ft. long, separated from the navigation pass by a pier 12 ft. wide and terminating in an abutment 17 ft. 6 ins. wide in the left or Kentucky bank.

The total length of foundation masonry, including the width of lock chamber and walls, and omitting wing walls, is about 400 ft., or about the original width of the river at the level of the top of the lock walls.

Lock.—The lock, which is of sandstone masonry, the stone being taken from local quarries, is 255 ft. in length, with a distance between quoins of 190 ft., and is 52 ft. in width. The walls stand 21 ft. above the lower miter-sill level. The chamber faces of the lock walls are vertical and cradle-faced; the outer faces are "stepped" at each course and are of pitch-faced masonry. The ends are also of pitch-face, and are vertical. The bases of the land wall, and of that part of the river wall adjacent to the chamber, are 15 ft. wide, and those parts of the river wall about the gates, and above the upper gate and below the lower one, have a base of 21 ft. The coping along the chamber is 7 ft. 6 ins. on each wall, while on the larger portion it is 15 ft. 6 ins. on the river wall, and 15 ft. on the land wall. Wing walls project from each end of the land wall into the bank.

The lower miter-sill was placed 9 ins. below the low-water mark of 1883, and the upper one 2 ft. above the lower. The gates are of wood, of the miter pattern, and are operated by hand. The cost of the lock, including everything properly chargeable, was $120 371.81.

Dam.—The successful working of a movable dam depends to a considerable extent upon the height of its sill and the length of its waterway; that is, the fixed parts should cause very little fall over their crests when the movable parts have been taken out; otherwise navigation will be interfered with at the stage just preceding that which necessitates the raising of the dam.

The dam at this place is divided by a pier into two parts, the navigation pass and the weir. The purpose of the former, as its name implies, is to accommodate navigation, while that of the latter is for the passage of surplus water. The pass is 130 ft. long with its sill about 1 ft. below the low-water line of recent years, and at the low-water mark of 1883. The weir is 140 ft. in length, and its sill is 6 ft. above that of the pass. The normal height of the pool is 13 ft. above the pass sill.

Fixing the Dimensions.—The considerations which led to the adoption of the dimensions given to the parts of this dam are set forth in a partial report made by Major D. W. Lockwood to the Chief of Engineers, dated March 1st, 1893, an extract from which is as follows:

"As the Big Sandy is subject to sudden changes and to rises of various heights, which frequently run out in a very short time, it is important that the character of the construction of the dam be such

that it can be operated rapidly and within certain limits as to rises, without interruption of communication between the banks.

"The dams on the Meuse have foot-bridges raised 18 ins. above the normal level of the pool, so that a slight rise will not flood it, and thus cut off communication across the river. These dams, however, have the pass fully closed by needles, the weir being furnished with Chanoine wickets. This plan would hardly work on the Big Sandy, as the low-water discharge would not be sufficient to supply the leakage, even with the joints between the wickets covered; at certain stages, also, there is considerable drift in the stream. And this would not pass by the weir with the wickets *en bascule;* while in the case of a weir closed by needles, these can be removed and as many trestles, next the abutment, as may be found necessary, can be lowered to permit the drift to pass.

"The type of dam adopted for the Big Sandy is similar to that employed on the Meuse for closing the passes. The trestles, however, instead of being forged out of iron, with a rectangular cross-section, are built of U-iron, joined by gussets and rivets. A different escapement for the bar supporting the upper ends of the needles has also been adopted. The trestles are spaced 4 ft. apart between centers.

"The dam is divided into two parts, separated by a pier: the navigable pass, through which the commerce of the river will pass when the natural stage is sufficiently high, its sill being placed at or below the level of the highest natural obstruction in the river, and the weir, the sill of which is placed considerably higher than that of the pass. One of the functions of the latter is to carry off the surplus water, beyond what is required to maintain the pool, at least for stages up to the one at which the natural river is navigable, and when the dam can be lowered entirely.

"In determining the length of sill of pass, the conditions that determine it are, that it shall present an opening that can be readily run by rafts and tows of the kind that can navigate the Big Sandy descending, and steamboats going up stream, while considerations of economy require that it shall be as short as possible, consistent with the service required of it.

"To satisfy the first condition, it is thought that the pass should have an opening of 130 ft. During the season of 1891, the lowest water recorded was 1.25 ft. above the low-water level at the time the lock was built, and the discharge, 100 cu. ft. per second, would indicate a close approximation to lowest water. With the gauge reading 1.25 there were from 8 to 10 ins. of water on the principal shoals, so it is concluded that if the sill of the pass be placed at the level of low water, as originally determined, or 0.75 ft. above the lower miter-sill of the lock, it will satisfy the condition of not being an additional obstruction.

"The elevation of the sill of the pass being determined, as well as its length, the next question to be settled is the difference of level between the sills of the pass and weir. As the head-bay and gate recesses would be liable to sand up, and a deposit of sand occur in the partially dead water below the lock, should the gates be closed while the pass is open, the area of discharge through the lock may be taken into account in the determination of the height of the sill of the weir, as this elevation results from a consideration of the discharge of the river, and the area of discharge through the pass and lock up to the stage which just covers the sill of the weir, with the conditions supposed that the swell head produced by the partial contraction of discharge area, shall not be sufficient to seriously interfere with navigation up or down.

"During the season of 1891, discharges, areas of discharge, and mean velocities were measured through two rises. The first reached a height of 11.15 ft., July 25th, and the second a height of 15.45 ft. August 25th.

"The discharge and mean velocities deduced from observations made during the rise of August 25th, taken on account of its greater range, and also because the discharges for stages up to the probable elevation of the sill of the weir are greater than those obtained in the first case, are as follows:

Stage. Feet.	Discharge. Cubic feet.	Mean velocity. Feet per second.	Stage. Feet.	Discharge. Cubic feet.	Mean velocity. Feet per second.
5	3 318	2.72	11	12 585	4.06
6	4 810	2.99	12	14 338	4.21
7	6 302	3.21	13	15 936	4.30
8	7 750	3.42	14	18 900	4.64
9	9 088	3.56	15	20 850	4.71
10	10 525	3.72	15.45	21 500	4.70

"Assuming a value of 0.5 ft. for the swell head, the question then is to determine the maximum stage of the river, the discharge corresponding to which will pass through the pass and lock without causing an increase in depth of water above the dam over that below the dam exceeding 0.5 ft. This will give the elevation of the sill of the weir above the sill of the pass.

"To determine this the Chanoine formula is used, to wit: *

$Q = M(L\,H + L'\,H')\sqrt{2\,g\,(Z + h)}$, in which:

Q = discharge of river per second;

M = constant depending on stage;

L = length of pass;

* "*Canalisation de la Meuse*," p. 86.

L' = length of weir;

H = height of water below dam above sill of pass = stage in this case;

H' = height of water below dam above sill of weir;

h_1 = height due to velocity of approach = $\dfrac{v^2}{2g}$.

"For any stage H the discharge through the pass will be $Q' = M (130\, H) \sqrt{2\, g\, (Z + h_1)}$, and through the lock $Q'' = M\, [52\, (H - 1.25)] \sqrt{2\, g\, (Z + h_1)}$, as the upper miter-sill is 1.25 ft. higher than the sill of the pass; so that for the pass and lock $Q = Q' + Q'' = M\, (182\, H - 65) \sqrt{2\, g\, (Z + h_1)}$. For $H = 5$ ft., $M = .703$, $V = 2.72$ ft., and the equation becomes $Q = .703 \times 845 \times 8.02 \times .784 = 3\,735$ cu. ft., which is considerably greater than the discharge corresponding to a 5-ft. stage. Making H in the formula equal to 6 ft., M becomes equal to .71, $V = 2.99$ ft., and there results $Q = .71 \times 1\,027 \times 8.02 \times .8 = 4\,678$, for the discharge by the lock and pass with a swell head of 0.5 ft. Z being taken equal to 0.5 ft., and the sill of the weir being 6 ft. above that of the pass, at a 6-ft. stage the discharge over the weir will be $L' \times .45 \times 8.02 \times .5^{\frac{3}{2}}$. Taking L' equal to 140 ft., the discharge over the weir becomes equal to 180 cu. ft. per second, so that the quantity of water that can pass the dam per second, the lock gates being open, without producing a greater swell head than 0.5 ft., is 4 858 cu. ft. The discharge of the river corresponding to a 6-ft. stage is 4 910 cu. ft. per second, so that the swell head corresponding to this discharge would be but little in excess of 0.5 ft.

"In determining the length of the weir, the following conditions must be satisfied: 1st. The area of discharge afforded by the weir must be sufficient, when taken in connection with those of the pass and lock, to permit the passage of discharges corresponding to all stages up to the level of the top of pier and abutment, without causing a greater swell head than 0.5 ft. 2d. The discharge area of the weir should be sufficient to pass all discharges corresponding to stages up to that at which the natural river is navigable, without the removal of any needles from the pass. It may be stated, however, that the second condition will be satisfied by a length of weir that will satisfy the first.

"To determine the length of the weir, the elevation of its sill being fixed, the formula of Chanoine, modified to take into account the discharge through the lock is used, to wit:

"$Q = M\, [L\, H + 52\, (H - 1.25) + L'\, H'] \sqrt{2\, g\, (Z + h)}$ or substituting for L its value already determined, 130 ft., the formula becomes $Q = M\, (182\, H - 65 + L'\, H') \sqrt{2\, g\, (Z + h)}$; making H equal to 7 ft. H' becomes equal to 1 ft., and the formula becomes $Q = M\, (1\,209 + L')$

$\sqrt{2\,g\,(Z+h_{\prime})}$. For a stage of 7 ft. $Q = 6\,362$ cu. ft., $M = .73$, $h_{\prime} = \frac{V^2}{2g} = \frac{(3.21)^2}{2g} = .160$ and $(Z+h_{\prime})^{\frac{3}{2}} = .812$, whence L' becomes equal to 129.3 ft.

"For high stages, the formula of Chanoine and De Lagrene* is used, to wit: $Z = 1.5\ V^2 \frac{(S^2-1)}{S^{12}} \frac{1}{2\,g}$ in which Z = swell head, V = mean velocity before construction of works, S = discharge area of river before construction of works, S' = discharge area after construction of works $= L\ H + L'\ H'$, and 1.5 is a constant for cases where the lock gates are open. Transforming the above equation and substituting for $2\ g$ and Z their values 64.3 and .5, respectively, there results $S' = \left(\frac{1.5\ \sqrt{2}\ S^2}{32.15 + 1.5\ \sqrt{2}}\right)^{\frac{1}{2}}$. For the highest stage observed $H =$ 15.45 ft., $H' = 9.45$ ft., $V = 4.7$ ft., and $S = 4\,576$ sq. ft., and $S' = L\,H + L'\,H' = 3\,260$ sq. ft. $= 2\,008.5$ sq. ft. $+ 9.45\ L'$, whence $L' = 132.4$ ft.

"As the stage that would just cover the pier and abutment is 16.5 ft., it is thought best to fix the length of the weir at 140 ft., particularly as the rises in the Sandy during the summer are generally quite sudden when the Ohio is apt to be low.

"With the sill of the pass at low-water level, and 130 ft. long; the sill of the weir 6 ft. above that of the pass, and 140 ft. long; for the 8-ft. stage Z becomes equal to 0.53 ft. for the 9-ft. stage it is less than 0.5 ft., and when the pier and abutment are submerged Z will not exceed 0.5 ft. appreciably."

Innovations.—The arrangements proposed in the foregoing report were maintained, except that, instead of adopting the design of trestles proposed, another, requiring less height of sill for its protection, was used. This form of trestle does not superpose, requires but little depth of recess, and has not heretofore been applied. This change of plan was brought about by the discovery that the recess below the pass-sill was constantly filled with sand, gravel and stones, and it was believed it would be impracticable to keep it sufficiently clean to properly maneuver the trestles.

The new form of trestle suppresses the axle and diagonal bracing of the old and gives a decided inclination to the posts and permits the trestles to lie one within another when down instead of piling up on each other as in the old form. Thus it is that a sill of sufficient height to protect one protects all, and a very shallow recess answers the purpose and greatly reduces the liability to sand up.

* "*Canalisation de la Meuse*," p. 88.

The method of maneuvering the trestles was also changed from that in general use. In the maneuvers of trestles, as heretofore generally practiced, a chain is attached to each trestle and a crab is moved along the foot-bridge, winding in the whole length of chain in order to raise the trestle. At best this is slow and laborious. The new method connects all trestles by a continuous chain which, when wound over a chain-wheel on a crab located at the lock wall, will successively bring the trestles into position by the winding in of a very short length of chain.

There are several modifications in the original designs of the trestles, made with a view to reducing the time of maneuvering, but they are of little importance and will not be specially mentioned here.

To meet the unprecedented conditions in a needle dam of a depth of pool of 13 ft. on the sill, with very little down-stream pressure and with the chance of the head being increased 1 ft. at times by the sudden appearance of a freshet which might materially raise the level of the upper pool before the dam could be lowered, it was necessary to provide needles of much greater thickness and width than are in use elsewhere. In order to handle needles of this size the old method of placing by hand was out of the question, and it was necessary to devise a new method. This was accomplished by placing suitable machinery on a boat, which boat is used as a storehouse for the needles when not in use.

Character of Foundation.—The dam is founded on sandstone, varying in depth below low water from 3 ft. at the lock wall to 24 ft. at the abutment. The material overlying this rock was largely sand and clay, but the part underlying the weir was covered with a 4-ft. layer of gravel and small boulders. The rock was rather soft on top and at places shelly and filled with coal seams. The soft and shelly parts and coal were all removed, and the bed prepared was a fairly good foundation upon which to build.

Substructure.—The substructure is of concrete and sandstone masonry. In the pass it is 22 ft. and in the weir 17 ft. wide at the coping. The pass masonry averages about 12 ft. in height, and the weir about 24 ft. Immediately overlying the bed-rock is placed a layer of concrete, varying in thickness, but averaging about 4 ft. On this bed of concrete, and near its up-stream and down-stream edges, are built two parallel masonry walls. The space between these walls

is filled with broken stone to within 7 ft. of the coping, and above this is concrete, and the whole is coped at the top to receive the superstructure. Toward the up-stream side the masonry is raised and a sill is fastened for the support of the needles and the protection of the trestles.

Trestles.—The pass is closed by 31 and the weir by 34 steel trestles spaced 4 ft. between centers. These trestles terminate in eyes at the bottom and are connected to journal boxes by pins. The pass trestles are 15 ft. 2 ins. high and weigh 1 140 lbs., and the weir trestles 9 ft. 8 ins. in height and weigh 920 lbs., and have a base of 9 ft. 10½ ins. and 6 ft. 5 ins., respectively. The width on top is 3 ft. 8 ins., and the floor or walkway is 3 ft. 2 ins. The trestle frame is made of 4-in. steel channels, weighing 7.25 lbs. per foot. The up-stream post is single. The down-stream post is made of two pieces, set apart and trussed. These two channels are close together at the bottom and diverge toward the top, so that one of them comes to the up-stream post at the level of the connecting bar, above which point it is riveted to the up-stream post, and the other goes to the top of the trestle. They are assembled by gusset plates and rivets. The frame thus formed is connected by two horizontal braces, made of angle-iron and riveted to the outside. A suitable frame for carrying the floor is also riveted to the outside of the main trestle head. The bar which forms the upper support of the needles, and connects the trestles with one another when all are standing, is hinged vertically at the pool level, so as to swing horizontally. The opposite end is formed into a hook, on its up-stream side, which engages with a lip or projection on the next trestle. It is held in this position by a crank-shaped rod, known as the jack-post, which may be turned from the walkway by a wrench when it is desired to let the bar swing free, the hook end passing through the space formed by bending the post. When in use, the post is held from turning by a latch, which is raised out when the wrench is dropped over the head of the post.

The trestles are connected at the top with sheet-iron floors, hinged to and falling with them. The opposite end hooks into the next trestle at two points, and a latch moved by the foot holds each section in position. Thus the trestles are rigidly connected by two independent constructions, and there is still a third, the maneuvering chain. The cost of the trestles and their connection with the masonry was $3 328.34.

In a frame bolted into the head of each trestle is a combined ratchet and chain-wheel turning on a horizontal axis. Over this wheel a chain passes from one end of the pass to the other; there is also a similar chain for the weir. One end of each chain is fastened, in the case of the pass, to the trestle nearest the pier, and in the case of the weir, to the trestle nearest the abutment. The other ends of these chains are wound on chain-crabs located respectively on the lock-wall and on the pier. By means of a pawl dropping into the ratchet, the rolling of the chain-wheel may be stopped, and when this occurs the trestle is attached to the chain and the winding of the crab will move it as desired. For instance, it is desired to lower the trestles. First, the support bars are all released; then the floor section of the end trestle is unhooked and the crab turned backward; the trestle, being pushed away by the attendant, pulls the chain as it goes down. When it has proceeded, say, 4 ft., the pawl of the next trestle is dropped by the attendant and thus it becomes attached to the chain. The releasing of the floor locks the pawl in the ratchet so that it cannot come out while the trestle is down.

To proceed with the lowering, the floor section is again released and a second trestle starts down. As more chain is unwound, other trestles are attached, and several will thus be under way simultaneously. To raise the dam the chain is wound on the crab, or rather over a chain-wheel on the crab, where it falls into a recess provided for it. The first trestle (being the last lowered) is brought up, and the attendant, standing on the wall, grasps the floor, which rests on the chain, and raises it a few inches. This raising depresses the opposite end on the point of the pawl and lifts it out of the ratchet, and thus allows the wheel to turn and releases the trestle from the chain. The pawl is held out of the ratchet by an automatic device which drops under it. As each trestle comes up, it is released from the chain by the attendant standing on the floor of the last one raised and slightly elevating the end of the floor-section just coming up. The floor-section is then hooked to the neighboring trestle while the crabmen are winding; thus the entire maneuver may be performed without stopping the crab, and the winding in of 4 ft. of chain each time brings a trestle into place.

Needles.—The needles are of white pine and are 12 ins. in width. The pass needles, 14 ft. 3 in. long, are 8½ ins. thick at the bottom and

$4\frac{1}{2}$ ins. at the top, and weigh when wet about 263 lbs. The weir needles are 8 ft. 3 ins. long, $3\frac{1}{2}$ ins. thick at the bottom and $2\frac{1}{2}$ ins. at the top, and weigh about 80 lbs. All needles are banded at the top and bottom and have iron handles at the top for convenience in handling, and suitable attachments for connecting chains to place and remove them. In the sides of the pass needles a shallow groove is cut in which it is proposed to introduce strips of rubber should it be found necessary to prevent leakage to any considerable extent. The cost of the needles was $1 303.82. The pass needles when not in use are stored on a boat built for the purpose. This boat is provided with two overhead tracks carrying trolleys for lifting the needles from the piles and carrying them to the end of the boat when they are to be put in the dam, and for piling them when they are to be stored. All irons are countersunk so that the needles lie flat on each other when piled.

Drift Boom.—This river carries a considerable quantity of drift. While this usually comes on stages of water at which the dam will be down, yet there are times when it arrives in great quantities with the first indication of a rise. This happens when a severe storm occurs in some of the neighboring creeks and causes a freshet of sufficient force to break the tie and log booms in the mouths of these creeks. This drift is a menace to the dam, and should it come at a time when it was necessary to lower the dam, it would interfere greatly with this operation, if not seriously injure or even destroy the trestles. To prevent such an occurrence, a boom has been built which reaches from a point some distance above, and on the opposite side from the lock, to the crib at the river wall of the lock. As the river makes a pronounced bend at the point of attachment of the boom, the boom is little less than a prolongation of the shore above, and it will readily guide the drift into the lock, where it can be locked through or held till the dam has been lowered. In construction the boom consists of four parallel timbers bolted rigidly together and having rudders at intervals of 30 ft. The movement of these rudders is controlled by a wire rope which connects them all and is wound on a capstan at the ends of the boom. Thus, by setting the rudders at any desired angle, the boom can be held out in the stream at any point required.

Cost.—The total cost of the movable dam, including every item that should be charged to the construction of pass, weir, pier and

abutment, was \$73 697.74, or \$245.66 per linear foot. Of this, the substructure cost \$226.48, and the superstructure \$19.18, per foot.

Maneuvers.—The various operations required in maneuvering are as follows:

(*a*) Raising the trestles.

(*b*) Placing the needles.

(*c*) Removing the needles.

(*d*) Lowering the trestles.

An explanation of these maneuvers will now be given, assuming that the various parts of the dam are understood from the preceding description.

(*a*) *Raising the Trestles.*—The raising of the trestles may be done in two ways: (1) by a crab located on the pier for the weir trestles, and on the lock wall for the pass trestles; and (2) by a needle boat anchored above and raising the chain passed over a sheave and leading at right angles to the dam to the drum of the engine. Up to the present time the latter method has been but little employed, as a suitable engine has not been provided.

By the first method the chain is wound in by two men at the stationary crab on the masonry. The chain passes over a sprocket wheel and drops through a hole in the masonry into the recess provided for the pass trestles in the pier, and into the manhole of the discharging culverts in the lock. As the chain is wound in, it brings up the first trestle and starts others. When the first trestle is nearly upright, the attendant, standing on the masonry, lifts the end of the floor section, which lies on the chain, a few inches, and this movement depresses one end of the pawl and raises the opposite end out of the ratchet on the chain wheel. When the pawl and ratchet are separated, rigid connection between the trestles and chain ceases, and the attendant can handle the trestle at will without the crabmen stopping the winding in. He hooks the floor-section into the place provided for it on the masonry, and fastens it with a latch moved by the foot, and then, standing on the bridge thus formed, he brings the escape or connecting bar into place with a hook made for the purpose, and turns the jack-post, which is fastened to the masonry, to lock it.

By this time the floor of the second trestle comes within easy reach, and he repeats the operation of slightly raising the free end, which releases it from the chain. He then hooks it into the first

trestle and latches it with the foot-latch. By a repetition of these maneuvers, the trestles are all brought upright and connected with each other. When the last trestle has been raised, a rolling bridge is drawn out from a recess in the masonry and connected with it, and thus a foot-bridge is completed from one part of the masonry to another. It will be observed that, by winding in the length of chain at which the trestles are spaced, each trestle is brought up. After the first one, which has a sufficient length of chain to reach from the top to the bottom of the masonry, plus the distance from the masonry to the head of the trestle when down, the length is generally 4 ft.; that is, the trestles themselves are 4 ft. between centers, and, by allowing 8 ft. of chain to each, it is only necessary to wind in 4 ft. of this to properly bring the trestles to position. The time taken to raise either pass or weir trestles is about 40 minutes.

(*b*) *Placing the Needles.*—This has been effected in two ways, (1) from the boat, and (2) from the water by a derrick on the boat. The first method was originally the only one attempted, but experiments have proven the second to be equally good and with much less work.

(1) The pass needles are stored on a boat, and are so constructed that they lie perfectly flat on each other when piled, so as to prevent warping and save space. Immediately over the piles of needles, on each side of the boat is a suspended track on which travels a trolley. The needles are all stored with their heads in one direction, toward the dam. At about the center of weight of each needle is a ring. The trolley has a sheave over which passes a chain having a hook at one end. By placing this hook in the ring of the needle, and pulling down on the free end of the chain, the needle will be raised from the pile. Near the hook is a catch or claw on the chain, the purpose of which is to hold the bight of that part of the chain pulled down in raising the needle. Thus, the needle, after being raised, remains suspended, and by pushing it the trolley rolls along the track overhead, and carries it out to the bow of the boat, the free end of the chain lying idle on the needle. The boat is placed so that its bow is only a few feet up stream from the trestles, and when the needle is brought to the end of the track its head projects over the foot-bridge. Here it is grasped by the attendant stationed on the trestles, and placed on the support bar along side the last needle put in. The trolley track projects over the hull of the boat several feet, so that when the head

of the needle is in its proper place on the trestles, the butt or foot is just at the bow. When all is ready a quick jerk on the free end of the trolley chain releases it from the claw, and the weight of the needle pulls the chain over the sheave. When the needle strikes the water the current carries it against the sill, the force of the blow being lessened by the men holding the free end of chain, thus allowing it to come to its place gradually.

When the strain is off the chain the hook drops out of the ring, and the ring drops into a recess made for it in the needle. A stage-plank projects about 15 ft. from one side of the boat parallel with the dam, so that it is possible to place about 30 ft. of dam, by allowing the needles to float out to position without moving the boat.

As the placing of the needles progresses, a swift current develops around the wall so constructed, and it is found necessary to hold back the needle being placed, in order to prevent it from moving along the sill. In the latest maneuvers the force of the current was broken by a screen with great satisfaction.

Fig. 1, Plate XV, shows the operation of putting the needles on shelves for simultaneous placing. After all the needles have been so placed, the throwing of a trigger will release the shelves and they will revolve and simultaneously drop all the needles into position.

Fig. 2, Plate XV, is a down-stream view of pass trestles and needles.

(2) In the second method, the needles are left in the river, instead of being stored on a boat, and are lifted from the water by a light derrick, operated by steam or hand, on the needle boat, and placed vertically, either on swinging shelves suspended on the up-stream side of the trestles, or on a suitably constructed frame resting on the sill at the bottom.

In placing the needles, every fourth one is put in its proper place against the sill instead of on these shelves or frames. These act as guides to the others when they are let into the water, and the shelves or frames themselves prevent the needles from being carried down stream by the current, and striking on top of the sill instead of above its shoulder. After all the needles have been placed on the rest-planks or frames, they are dropped into the water as rapidly as practicable, and the whole dam is in before the head has appreciably increased. The shelves or frames are then loosened and taken to the bank.

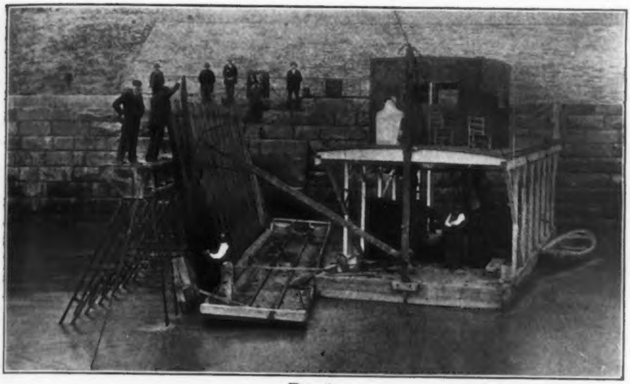

Fig. 1.

Fig. 2.

Further studies are being made with a view to simplifying the placing of the needles, and the experiments so far made indicate beyond a doubt that all the needles can be placed within a few minutes after they have been gotten ready, without increasing the head beyond a few inches, and that the only thing remaining to be decided is the best means of accomplishing this result. This can only be determined by further experiment and study.

Originally after the pass needles were placed, those of the weir were put in. When the water was warm, an attendant stood on the masonry above the sill and placed the needles at the bottom while another attendant held the head. If the water was too deep or cold for the application of this method the needle boat could be used, or the attendant could stand in a light boat above and guide the needles into place, and, by holding back, could break the force of the blow when they struck the sill. As at present arranged, the weir needles are placed before those of the pass and while there is still some water on the weir sill. This is easily and rapidly done by men standing on the masonry above the sill and taking the needles from a light boat or directly out of the river. The principal advantage of this method is that the closing of the weir increases the current through the pass, and tends to scour out deposit on the trestles, which are not raised until after the weir is completed.

(c) *Removing the Needles.*—When a rise approaches, the wickets in the lock are opened, and when they fail to keep the pool down to its normal level alternate needles are *repoussed;* that is, the heads of alternate needles are pushed up stream and pins or sticks 12 to 15 ins. long placed between them and the support bars. This permits the escape of a great quantity of water. When this fails to keep the pool down, the weir needles thus standing out may be entirely removed, or, if indications point to a considerable rise, all the weir needles may be removed by the method explained further on. A continuation of the rise may necessitate the removal of all the needles standing out in the pass or even the whole of the pass, which process will now be explained.

Near the top of each needle is a countersunk handle for use only in removing the needle. A chain much longer than the length of the dam is passed along the up-stream side of the needles and connected by hooks with these handles. There is a considerable length of slack

chain between each pair of handles. The end of the chain is fastened to a long line leading to the engine on the needle boat, which is anchored well up stream, or to a crab on the lock wall, or on shore. By starting the engine or crab the first needle is pulled away from its support at the top, and when it has traveled the length of the slack chain leading to the next, the second is started, and so on until all are removed and are afloat. This maneuver is very rapid, the time required being simply that which is necessary to wind the rope on the drum of the engine. The boat is anchored in such direction that the needles float into the quiet water above the unremoved portion of the dam.

The original intention was to adopt the escapement method of removing the needles, and this can still be used if desired, but it was found that the wide needles would be greatly damaged, particularly on the weir, by allowing them to fall down stream. The method employed is more rapid and less destructive to the needles and in every way more satisfactory. Were the trestles of wider span, the escapement method would be preferable, on the weir, at least, but the lack of a cushion of water on the masonry would often prevent escaping on account of injury to the needles.

(*d*) *Lowering the Trestles.*—In lowering the trestles, the last one raised is the first to start down. The attendant stands on the footbridge and first unhooks the rolling bridge and pushes it back into its recess. He then disconnects the escape-bar of the last trestle and throws it around against its trestle and then unhooks the floor section, which falls on the chain and rests there; he gives it a push, and the man at crab at the same time slacks on the brake so as to unwind the chain. When the chain has run out about 4 ft. the attendant throws the pawl of the standing trestle into its ratchet and thus the descending trestle is stopped. The escape-bar and floor section of this trestle are then released and the weight of the trestle already under way pulls it towards itself when the chain-wheel of the crab is allowed to turn, thus paying out the chain. The operation of throwing the pawl in the ratchet is again repeated, when the chain has gone as far as desired. A repetition of these maneuvers brings all the trestles to their beds with their floor section resting on top of them. In this manner four or five trestles are descending simultaneously, and as fast as one comes to rest, another is attached. The time required for lowering either pass or weir is about 20 minutes.

PLATE XVI.
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FIG. 1.

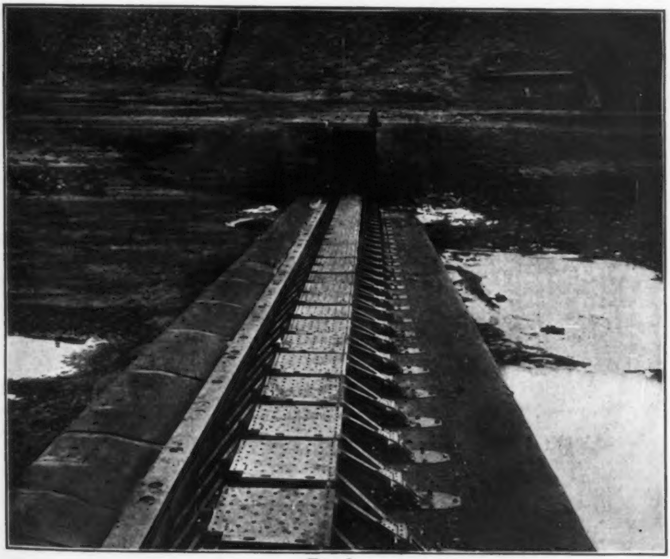

FIG. 2.

By the lengthening of the chain, it has been made possible to lower each trestle separately, if desirable, during a heavy run of drift, or for other reasons. In this case the chain can be spaced beforehand, and the operation of lowering will consist simply of releasing the connection between the trestles and allowing them to fall, as is done with the old-style trestles, or they can be lowered with the crab, the pawl of the standing trestle not being thrown into the ratchet until the trestle which is being lowered comes to rest. In this case a line pulling from the opposite end of the dam would be required to start the trestle downward, but a better solution would be to throw in the pawl a little before the descending trestle came to rest. Its weight would then start the next trestle when released.

Fig. 1, Plate XVI, shows the operation of lowering the trestles of the weir. Fig. 2, Plate XVI, is a view of the weir trestles down.

Results.—The dam has, at this writing, been in operation nearly one year. The early part of the present season was one of violent thunder storms and sudden freshets, which brought much driftwood into the river. About the last of July a drouth set in which was of unusual duration. The discharge of the river became reduced to less than 50 cu. ft. per second. The pool has remained full at all times, except when drawn off to assist small craft below or perform necessary work about the lock and dam. The greatest head so far attained was 12 ft. $2\frac{1}{4}$ ins., and the leakage through the pass was only 5.19 cu. ft. per second, and that of the weir too small to take into account, being but 1 gall. in 38 seconds.

No trouble has been experienced with the pass; the needles have been removed and placed, and the trestles have been lowered, each time without difficulty of any kind. In raising the trestles the chain was broken on two or three occasions, caused by heavy deposits of sand on the floors which form the foot-bridge when up. With one exception this has occurred only on the trestles which lie in the pier recess. It has been found impracticable to leave the lock gates open on account of the increase of this deposit, due to the greater discharge section and consequent reduction in current velocity. By closing the lock and erecting the weir some time before the water level reaches its masonry crest, considerable scour takes place through the pass, and no further trouble from this deposit is anticipated. In the pier recess the removal of the floor sections, before lowering the trestles, will pre-

vent a deposit of sufficient weight to break the chain. On the weir there has been a little trouble with drift, but it was of slight consequence. The raising of the trestles and the removal and placing of the needles is done with the greatest facility. What difficulty there has been has arisen from permitting the trestles to stand after the removal of the needles in the drift-laden torrent caused by the release of so much water. The larger drift is held back by the boom, but small pieces, brush, etc., are drawn under the boom by the increased current, caused by opening the dam, and some of this lodges against the standing trestles. With trestles of wider span, and by lowering the trestles simultaneously with the needles, most, if not all, of this difficulty can be obviated. It has not been practicable to do this, however, owing to lack of bank protection below the abutment. The opening of the needles from the abutment end of the weir causes great scour for some distance below and endangers the paving, so that it has been considered advisable to make the first openings in the dam at the pier end. Thus it was necessary for the trestles to stand until all the needles were removed, when the lowering could begin at the abutment. Even with this drawback, the total delay caused by drift has not exceeded two hours in the whole year, and but one trestle has been bent and only slightly.

On account of the great quantity of drift running in this river, it was originally proposed to use wickets on the weir, raised without the use of a foot-bridge and lowered by a tripping bar; thus no trouble would be encountered by drift lodging against the trestles as now occurs on wicket dams operated from trestles. This arrangement, in the light of experience, would have been preferable, so far as disposing of the drift is concerned, but the leakage would have been more than the entire low-water discharge of the river, unless improvements could have been made over those now in use. Either method has its objections and its advantages, and neither is wholly suited to a weir through which drift must pass. The only serious objection, outside of the lodging of drift on the trestles, is the difficulty of replacing the wide needles under the full head after they have once been removed to pass a moderate rise, but even this is not impossible and is rarely necessary. The width of weir needles can be advantageously reduced without seriously increasing the leakage and thus assist materially in this contingency.

PLATE XVII.
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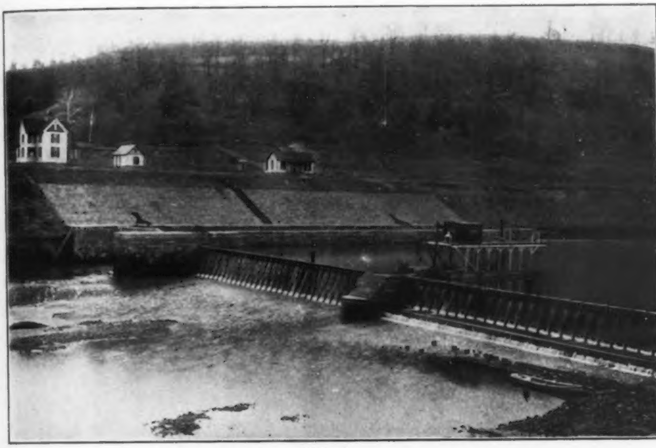


FIG. 1.

FIG. 2.

In addition to the leakage, wickets would be objectionable on this weir because they could never be put on the swing for fear of driftwood lodging against the horses and thus complicating the maneuvers. Thus, pool regulation could not be effected in small rises with the certainty that it can by *repoussing* needles; but they have the advantage that they can be raised against the full head of water at any time desired, and thus prevent too great a lowering of the pool in passing small freshets. The author believes that the construction could be so altered as to greatly decrease the leakage and thus to a considerable extent eliminate this objection. Considering the untried methods necessary in this dam, it may be said that the maneuvers have all been fairly satisfactory so far. The dam has been operated in one or two instances under especially difficult conditions, and it is safe to predict success under all ordinary circumstances which may occur. A rapidly rising river, filled with drift, arriving at night, in snow or rain, might complicate matters considerably, and change an apparent success into a certain failure, without warning. All precautions possible, except the construction of telephone lines owned and operated by the Government, have been taken to provide against surprises, and results are now to be awaited and difficulties met with courage and intelligence.

The experience so far gained with this dam indicates that its operation will be at least as speedy, easy and safe as is that of the wicket dams on the Great Kanawha or of the needle dams of the old type in Europe, while this dam is much less wasteful of water than any of these, which is an important item in this and many other streams.

Fig. 1, Plate XVII, is a view of the Louisa dam from below, on the Kentucky side of the river. The pool is 3 ins. above the normal level and is running over. The head is 12 ft. 3 ins. from pool to pool. The depth on the sill is 13 ft. 3 ins.

Fig. 2, Plate XVII, is a view from the lower end of the lock when the pool is full. The difference in level between the two pools is 12 ft. 2 ins. It will be seen that there is no leakage perceptible throughout the entire length of dam, and that the water below is quiet.

Modifications.—With modifications having in view the disposal of the drift, that is, setting aside a certain part of the dam for this purpose and constructing it with that object in view, the needle dam may become an economical and safe means of improving American rivers

of all sizes and characters. At this particular dam, improvements could be made: by providing a drift chute for the passage of small débris and for regulating the pool; by increasing the spans of the trestles so that the escapement of needles will be facilitated and the passage of drift at the time of opening the dam be rendered less dangerous; by widening the pass needles in order to consume less time in placing them and also make their escapement less injurious; by cutting off the needles at pool level so as to permit an overflow, the same as wicket dams have, and thus assist in pool regulation at the ordinary stage of the water.

While these changes would be beneficial on the pass, yet they are not absolutely necessary. There is little doubt that the form of dam for closing the weir on a river similar to this, with its great quantities of drift and sudden rises, could be advantageously changed in new constructions; still the author is not ready to condemn a needle weir, by any means. The weir should be capable of rapid and safe operation under the most adverse conditions. It should not only be possible to lower it, but also to raise it, under full head of water; for there are times when it is advantageous to discharge a rise over it without lowering the pass at all, and it should be raised again long before the pools above and below reach the same level. It should be practicable to completely lower a part of it for pool regulation and raise it again at the proper time without reducing the head below pool level.

That this result may be economically accomplished by the proper construction and intelligent operation of well-known forms of dam the author has no doubt. There has been in use for nearly seventy years a type of dam which may be applied for this purpose with great economy and assurance of success—the Thenard shutter. The width of the shutters must be only such as the power at hand will raise, against the maximum head of water, whether this be as narrow as an American needle or as wide as a Chanoine wicket. This power may be applied in the ordinary way from a foot-bridge, or maneuvering boat (the foot-bridge being lowered again after use), or the maneuvers may take place in a conduit in the masonry. The lowering will, of course, be accomplished by a tripping device of suitable design, operated from the masonry or from the conduit mentioned.

That the same result may be attained with the dam described further on, composed wholly of trestles without needles, gates, curtains or wickets, in which the maneuvers are across the current from stationary mechanism, seems reasonable, and the bear-trap and drum wickets may be called into play for this purpose, because the initial head can be obtained by raising the navigation pass first.

Calculations.—The strains on the various parts of the dam will now be given.

Pass Trestles.—Direct strains. If the water is 1 ft. above the normal level of the pool the total pressure on each bay of needles will be 4 ft. 0 in. × 13 ft. $3\frac{1}{2}$ ins. × 62.5 lbs. × 7 ft. 6 ins. = 24 900 lbs.

Taking moments about the sill to find the pressure P on the support bar connecting the trestles at pool level, the distance to the resultant pressure being 4.72 ft.:

$$P = \frac{24\,900 \text{ lbs.} \times 4.72 \text{ ft.}}{13 \text{ ft. } 3\frac{1}{2} \text{ ins.}} = 8\,900 \text{ lbs.}$$

The two down-stream pieces are rigidly connected and may be assumed to take equally the strain they bear, whence, by graphics: Tension in up-stream post = 11 000 lbs.

Compression in two down-stream posts = 7 400 lbs. each.

Stress in up-stream post for 4-in. 8-lb. channel $= \frac{11\,000 \text{ lbs.}}{2.4 \text{ lbs.}} =$ 4 600 lbs. per square inch.

Stress allowable, about 12 000 lbs. per square inch of net section.

Stress in down-stream posts $= \frac{7\,400 \text{ lbs.}}{2.4 \text{ lbs.}} = 3\,100$ lbs. per square inch.

With square and pin bearing the allowable stress for steel per square inch would be 7 000 lbs. if $\frac{l}{r} = \frac{15 \text{ ft. } 0 \text{ in.}}{1.47} = 10.2$.

Indirect strains are caused by the maneuvers, sediment, suction, etc.

When the pass trestles are down, deposit covers them and encloses them to the level of the top of the sill. It may be assumed that each post, in being raised, must lift, for each foot of its length, a block of material 9 ins. wide by 8 ins. deep. Then 9 ins. × 8 ins. = 72 ins. × 12 ins. = 864 cu. ins. = 0.50 cu. ft. Net weight of sand in water = 110 lbs. — 62.5 lbs. = 47.5 lbs. or say 50 lbs. per cubic foot. Weight of posts and connections, say, 10 lbs. per foot run.

Hence total weight on post $= \frac{50}{2} + 10 = 35$ lbs. per foot run.

Greatest length between supports = 16.5 ft. Hence bending moment $= \dfrac{35 \text{ lbs.} \times 16.5 \text{ ft.} \times 16.5 \text{ ft.}}{8} = 1\,190$ ft.-lbs. $= 14\,200$ in.-lbs.

Now if s = strain per square inch in extreme fiber,

c = distance from center of gravity to same fiber,

I = moment of inertia of section,

M = bending moment,

then $s = \dfrac{Mc}{I} = \dfrac{14\,200 \text{ lbs.} \times 2 \text{ ins.}}{5.1} = 5\,600$ lbs. per square inch for 4-in. 8-lb. channel. Compression strain due to raising = about 200 lbs. per square inch. Total strain in raising = 5 800 lbs. per square inch.

The actual weight of one trestle head, with floor, escape-bar, etc., with bottom of trestle resting on ground, is 750 lbs. Assuming that 900 lbs. is the weight raised by the chain in raising according to the diagram, then maximum pull on chain = 4 360 lbs.

Pass Needles.—These are 12 ins. in width, $8\frac{1}{2}$ ins. thick at the bottom and $4\frac{1}{2}$ ins. thick at pool level. Clear span = 13.3 ft. Maximum head = 13 ft. Pressure per needle = 1.0 ft. × 13.3 ft. × 6.5 ft. × 62.5 lbs. = 5 400 lbs.

Maximum M will be found at 7.5 ft. below pool level and $= (1\,800 \times 7.7 \text{ ft.}) - (1 \text{ ft.} \times 7.7 \text{ ft.} \times 3.75 \times 62.5 \text{ lbs.} \times \dfrac{7.7 \text{ ft.}}{3}) = 13\,900 - 4\,600 = 9\,300$ ft.-lbs. $= 111\,600$ in.-lbs.

Thickness of needle at this point $= 6\frac{3}{4}$ ins. From standard formula, extreme fiber strain $s = \dfrac{Mc}{I}$; $c = \dfrac{6\frac{3}{4} \text{ ins.}}{2} = 3.37$ ins.; $\dfrac{c}{I} = \dfrac{3.37 \text{ ins.}}{I} = \dfrac{6}{12 \text{ ins.} \times 6\frac{3}{4} \text{ ins.}} = \dfrac{1}{91}$. Then $s = \dfrac{111\,600}{91} = 1\,230$ lbs. per square inch.

For needle $7\frac{1}{2}$ ins. thick $s = \dfrac{111\,600}{112} = 1\,000$ lbs. per square inch.

For needle 8 ins. thick $s = \dfrac{111\,600}{128} = 875$ lbs. per square inch.

The leakage through the pass when the pool is at normal height, 13 ft. above sill, with no down-stream pressure = 20.5 ft. × 0.6 = 12.30 ft. per second. Area of opening with needles $\frac{1}{8}$ in. apart = 13 ft. $3\frac{1}{2}$ ins. × $\frac{1}{8}$ in. = 0.138 sq. ft. Hence leakage per needle (or per foot) = 12.30 ft. × 0.138 sq. ft. = 1.70 cu. ft. per second.

Hence total leakage between pass needles = 1.70 cu. ft. × 131 = 222 cu. ft. per second. De Lagrene's formula gives the leakage as

about 196 cu. ft. per second. In actual practice, there is not the least leakage in six or eight consecutive joints, and it is safe to state that water passes through less than one-third of the joints, and even these may be closed by the use of grass and weeds. The weir leakage amounts to 121 cu. ft. per second by the same formula. In practice, it probably never equals one-fiftieth of that amount, and most of this occurs between the sill and the needles where small stones or sticks may have caught. With a head of 7 ft. on October 22d, 1897, the leakage through the weir was all collected on the masonry floor and passed through a small pipe, and amounted to a common water bucket full in 95 seconds, or about 1 gall. in 38 seconds. The entire leakage of pass and weir was carefully measured at the same time and found to be about 5.20 cu. ft. per second. The discharge of the entire river had at that time been reduced by the long drouth to 48 cu. ft. per second. The river below the dam then stood at 10 ins. on the pass sill, and the distance to the level of the upper pool was 12 ft. 2¼ ins.

Remarks on Needle Dams.

Needles.—The two principal objections to needle dams, of lifts even as high as those sustained by wickets, have been that the needles would be too heavy for one man to handle and that the leakage would be too great. Both of these objections have been overcome, in the dam just described, by the use of needles handled by machinery, and of such dimensions as to make practically a tight wall. The width of the needles causes but few joints, and these are reduced to the smallest space by carefully placing them close together; the thickness or depth being of great advantage in holding sediment, weeds, grass, etc., which are drawn into the joints. In this dam, while the depth of water is 13 ft., the head sustained is 11½ to 12 ft., and may even go to 13 ft., because there is no dam below to hold the water to a certain height, yet the leakage can be reduced to almost nothing.

Now, in a system of dams, the head here sustained is practically the same as it would be in a dam with 18 ft. on the sill and 6 ft. in the pool below, and the author has no hesitancy in recommending such a dam under certain conditions.

High-Lift Dams.—These conditions are:

(1) The trestles should have a span as great as their height, or at least sufficient to enable one to be lowered independently of the others.

(2) The trestles should be provided with suitable escapements and appliances for placing the needles.

(3) The needles should be a combination of wood and steel or iron, 3 or 4 ft. in width and of great strength and stiffness.

(4) A regulating weir should be provided whose closing apparatus should be such as can be readily operated both in raising and lowering, in whole or in part, under the full head it sustains.

Wide-Span Trestles.—The chief advantage of wide-span trestles is that they permit any trestle to be lowered at any point in the dam regardless of any other trestle; a second advantage is that they allow most of the drift to pass through when the needles are being escaped, and even when it lodges the trestles are so strong that it can do but little damage before it can be removed. The wide spans are also quite advantageous in the escapement of needles, because these cannot be injured by striking the trestles in falling, like they can in the narrow spaces.

Escapements.—The best method of removing the needles is to permit them to fall down stream when there is a sufficient cushion of water to prevent their injury, and where the construction is such that they will not be damaged by the trestles or inflict an injury on these members themselves. For wide-span, high-lift trestles, the escapements which require the bar to swing horizontally will scarcely be practicable, but there is no doubt an escape-bar can be so constructed as to either revolve, slide or roll upward when released and permit the needles to pass under it; or hook or chain connections can be made which will support the tops of the needles and be readily disengaged when desired. The raising of the trestles can be easily accomplished, whatever their weight, within reasonable limits, and their upward pull on the masonry can be distributed so as to effect no injury.

Placing Needles.—The placing of needles of great width can be done with the greatest facility by arranging them so that all will drop into the water together. Suitable connections with the trestles can be devised for this purpose. The needles may be taken from the water by light machinery on a boat, or from any point desired by a small traveling crane running on a track on the trestles themselves, and placed upright on shelves of supports arranged beforehand. These supports should be so constructed as to guide the needles into the shoulder of the sill. When all is ready the simultaneous release

of the support-shelves will drop all the needles into the water together. This method has had a sufficient test to indicate its complete success in practice. It has the advantage that the needles come to rest without shock to the sill, dropping as they do almost vertically.

Another method which has merit, although not yet tried, even experimentally, consists in placing the heads of the needles on the escape-bars and suspending the bottoms just above water from a wire rope stretched across the pass. The needles are thus inclined up stream. When all have been put in position, both ends of the rope are released and the current carries the needles against the sill. It is not certain that this sudden striking of the sill will not be injurious both to the needles and the sill, although it is not believed that the force will be sufficient to do any damage, and another method on this line is suggested :

At the correct distance above the needles is placed a bar of steel reaching the entire width of pass. When down it rests on a sill at the level of the pass sill; when up it rests on legs or small horses hinged to the sill at the bottom and to the bar at the top. These legs do not become wholly upright, but stand inclined at a considerable angle to facilitate lowering. The bar is raised by winding in a chain attached to the end. When up it is just above the water. The bottoms of the needles are placed on it and the heads on the escape-bars. When all have been so placed the releasing of certain fastenings at several points will permit the bar to revolve and drop the needles into the water, when the current will carry them against the sill. In either case several needles should be put in place to act as guides, but not a sufficient number to materially increase the velocity of the current. The bar is then lowered by slacking the chain.

For the wide-span trestles, and wide needles mentioned at several points in this paper, the following method is suggested:

The trestles are connected at a suitable height with bars at up-stream posts. The needles are placed horizontally or nearly so on these bars, like a wicket on its horse, so that when the up-stream ends are depressed they will come to place in the shoulder of the sill by revolving around the bars, on which they are held by suitable projections or hooks. Special needles above each trestle may first be placed to fill the spaces. The bars can be removed when proper con-

nection with escape-bars above has been made. By this method, which can also be applied on narrow-span trestles, the needles can be righted more leisurely, as in Chanoine wickets, but it is advisable to do it quickly. There is no difficulty in arranging suitable appliances for simultaneous righting throughout the entire length of the dam, by simply placing the bars at such level as will make the butt of the needle heavier than its top, and holding the top on the under side of another bar or chain which, when released, will be raised by the upward movement of the heads of the needles as their bottoms go against the sill.

Tightening Jacks.—The tightness and cheapness of a needle dam are its two chief recommendations. By the use of heavy hydraulic jacks at the masonry ends of the pass, applied as soon as the needles have been placed and before the head has become much increased (and common jack-screws at intervals along the dam in wide passes), the needles can be pressed so closely together that no leakage whatever will take place between them. The author has used the common jack-screw for this purpose with great satisfaction by simply standing out the heads of needles at intervals and inserting the jacks between those in place. In this manner he was able to completely close all joints within 20 ft. either way from the jack with the great head of 4 ft. There should be two stationary jacks at each end of the pass, one near the top and one at the bottom of the needles. Those at the top need have but little power. All should be placed in recesses in the masonry and connected with needles in the recesses which would be pushed out to close the spaces made by pressing the needles together. Jack-screws of the common type may be used at intermediate points, if desirable, with great advantage, the spaces they cause being closed by joint covers or narrow needles.

Application to Wide Passes.—That it is wholly practicable to operate very wide passes, such as those proposed for the Ohio, closed with needles 3 or 4 ft. wide and 18 to 20 ft. high, with actual lift of 12 ft., the author has no doubt. That such a dam would be preferable to Chanoine wickets in many respects, particularly those of tightness and economy, is also true. The new idea of placing the needles simultaneously, coupled with the old one of releasing them by escapement, conspire to render it possible to close passes of any width without an increased head, and open them, if necessary, under full press-

ure. By the use of wide-span, heavy trestles, which can be dropped as fast as the needles are released, the danger from drift is greatly reduced, if not wholly overcome.

The maneuver of lowering may be as rapid as desired. Certainly this can be done with far greater speed than with wickets without a tripper. It can even be accomplished from the walls, without going upon the foot-bridge at all, if desired. The raising may require more time than for wickets, but this is not certain. By the use of a different form of floor for the foot-bridge the accumulation of deposit on the trestles when down will not nearly equal that which now finds lodgment on the wickets, and in this way much time may be saved in the raising. An advantage of needle dams, not to be overlooked, is the facility with which repairs can be made; every movable part is easy of access. The width of foundation for a needle dam need only be about one-half that of a wicket dam operated from a foot-bridge, and, as the cost is largely in the substructure, it will be much cheaper.

Needles Below Trestles.—The author has under way plans for a high-lift needle dam in which the needles are on the down-stream side of the trestles. The heads of the needles are supported by hooks attached to the down-stream side of the floor and the bottoms rest against a shoulder in the foundation. The supporting hooks are made with lever handles so that they may be readily disengaged either separately or by numbers as desired. The escape-bar is, therefore, not necessary. The down-stream posts of the trestles may act as part of the dam or the needles may be entirely below the line of trestles. The advantages of this construction will be apparent to those familiar with the maneuvers necessary to place and remove the needles, as they can be much more easily put in with the trestles to guide them and will not strike, or become entangled with the trestles, when being taken out. The pressure against a high sill at the bottom is also avoided. It is the author's intention to more fully describe and illustrate this idea in the discussion, when the drawings will have been completed.

Chanoine Wicket Dams.

The wicket dam invented in 1852 by M. Chanoine has had quite an extended application. It has undergone few changes, considering the number in use, but the form of hurter or shoe against which the

props rest when the dam is up was considerably altered by M. Pasqueau in 1879 in the dam at Lyons, France, and this modification has been applied in America. The object of this alteration was to dispense with the tripping bar in lowering the dams, but a French engineer has well said that this* "removes one of the greatest advantages of the Chanoine system; in suppressing the tripping bar we take away the power of opening the dam in a few minutes by the simple machinery of a crab on the bank, and in spite of any ice. In fact certain dams on the Upper Seine have been opened several times without difficulty and without damage when the river has been completely covered with ice, a notable example being that of the 25th of December, 1870, at Port à l'Anglais during the siege of Paris."

History.—As the Poirée dam was developed from the old-time stanches and plank dams of various patterns, so the Chanoine wicket dam is an evolution of another type. Gates with horizontal axes fixed in the abutments have long been in use. The valves used in the dikes of Holland turn on an axis near the top, and the date of their introduction is not known. They allow the water to run off at low tide and prevent its encroachment at high tide.

De Cessart, in 1808, proposed a wicket whose axes should be at the lower third of the height and turn in the abutment. A similar gate was proposed by M. Frimot in 1827.

The dams on the Orb (1778) were supported by hinges fastened to the floor of the dams. M. Thenard then added the prop, hurter and tripping bar, and at the suggestion of M. Mesnager the counter-shutter was constructed by him. The invention of M. Chanoine (1852) placed the axis of rotation near the middle of the wicket, above the center of pressure and on the down-stream side. The wicket is mounted on the head of a horse or trestle, upon which it swings. This horse is free to rotate around its base, which is hinged to the floor. The wicket is raised end-on to the stream. Its thickness and that of the horse and prop furnish the only resistence to the force of the current. When raised the wickets form the dam. They may be lowered either by the use of a tripping bar or by a boat-hook. These dams usually consist of two parts, the weir and the navigable pass. In the pass, the sill is level with the bed of the river. On the weir, the sill is considerably higher. The two portions of the dam are separated by a pier and are furnished with abutments at the banks. In the earlier

* Talansier in *Le Fénie Civil.* Vol. xiv, p. 20, November 10th, 1888.

times, the wickets were raised by the use of a boat, but in more recent dams a foot-bridge of Poirée trestle has been regarded as better, although the pass at the Davis Island dam, on the Ohio River, is maneuvered from a boat, and has the advantage that there are no trestles to catch drift.

Chanoine Dams, Proper.

Wickets.—It is not considered necessary at this point to describe other than the movable parts of a wicket dam. Wickets consist of three parts: a rectangular wooden or iron panel, capable of being balanced by counterweights on a horizontal axis, a horse and a prop. The horizontal axis of the wicket is generelly placed near the lower third of the height of the dam. When the water rises above the top of the wicket to a certain height, the wicket tips by the weight to an almost horizontal position. When the level of the pool is lowered the pressure is reversed, and the wicket is closed. In some of the French dams, the wicket is furnished with a movable counterpoise. When the level of the water becomes sufficiently lowered the counterpoise slides down to the lower end of the wicket, causing it to assume an upright position. The use of counterpoises is not in favor.

In the navigable pass the wickets are generally made so as not to turn automatically. This would be undesirable, for several reasons. These wickets are sometimes furnished with *papillons*, or flutter valves, which are so made as to turn on an axis when the stream attains a certain level. They are intended to regulate slight variations in the pool.

The portion of the wicket above the axis of rotation is called the chase; that below is termed the breech. When raised, the breech rests against the sill of the floor. The axis of rotation of the wicket is formed by the head of an iron horse, which itself revolves around a horizontal axis fixed to the floor.

The normal level of the pool should give the required level of water on the miter-sill. It has been calculated that, to maintain the proper level, the pass and weir wickets should be of the same height, and should be on a level with the upper pool when raised. If some of the wickets, either in the pass or on the weir, are lower than others it is difficult to maintain a sufficient head of water.

The wickets are not so constructed as to form tight joints one with another. In such a case any slight warping or lateral oscillation

would render their operation impossible. A space of from 4 to 5 ins. is left between adjoining wickets. This facilitates operation, and allows the low-water surplus to escape. If it is desired to conserve the water above the dam, it may be done by nailing strips to the edges of the wickets or by inserting needles at the joints. This operation may be performed with safety from a skiff or from the foot-bridge. The joints of the wickets in the pass should be closed first, because they are not likely to swing, and because the leakage is greater.

The width of the wickets is arbitrary, but it decreases with the height. The statical pressure is proportional to the product of the width into the square of the height. The rule should not go so far, however, as to abridge the width of the horse, and, thereby, the stability of the wicket. On the Haute Seine the wickets are 4.26 ft. wide for 6.56 ft. in height, and 3.28 ft. wide for 11.80 ft. in height.

The material used for the panel of the wicket may be either iron or wood. In time, wood is likely to warp, or rot, or open. While iron cannot be objected to on these accounts, it has the disadvantage of greater cost, and of not losing its weight in water. It is hence more difficult to maneuver.

When raised, a wicket is supported by the horse, which stands vertical, and the prop, which is inclined down stream. The wicket is inclined down stream at an angle not to exceed 20 degrees. When the foot of the prop is tripped, and it moves down the slide, the horse turns round its axis and falls to the floor as a continuation of the prop. The panel falls on top of the horse and prop, and protects them from the action of the current and from floating bodies. The panel should fall on a cushion of water formed by the lower pool, and, if it does not, it is likely to be broken or injured by the shock. The wicket is supported by a wrought-iron prop, the foot of which rests against a cast-iron hurter which is fixed to the floor. This hurter consists of an inclined plane, trapezoidal in form, $13\frac{1}{2}$ ins. long, $9\frac{3}{8}$ ins. wide at the base, and $3\frac{1}{8}$ ins. at the top. It is provided with lugs on the oblique faces $1\frac{1}{8}$ ins. thick, and projecting $2\frac{1}{4}$ ins. The front of the inclined plane, 4 ins. high and $4\frac{5}{8}$ ins. wide, terminated at one end by a lug of the inclined plane which projects at an angle of 45°, and at the other end by a slide with a lug $2\frac{5}{6}$ ins. high. Between the oblique lug of the cast-iron shoe, this reaches to the girder which

bears the tripper 1.44 ft. up stream. The total length of the slide is 5 ft., so that the end of the prop does not leave it when lying down, but curves to one side. The hurter and the slide form two pieces united by tenons. The hurter is so placed that the middle of the inclined plane, and the middle of the end of the slide are in a plane normal to the wicket and containing the axis of the prop. When the wicket is lowered the tripper pulls the foot of the prop into the slide, and, as it has no support, it is guided down the slide by a lug to the floor. When the wicket is raised, the foot of the prop follows the vertical plane over the top of the inclined plane. It is held upon the plane by two lugs. When at right angles to the front, it falls on the shoe and is in position.

Tripping Bar.—To lower the wickets a tripping bar is used. If the floor of the wicket exceeds 1.64 ft. above low water, the tripper is unnecessary, and the props are removed by a hook. The tripper has as many claws as there are props. If the pass exceeds 100 ft. in width, the bar is divided into two parts, which join end to end and work in opposite directions. They are operated by two windlasses, one at the abutment, and one at the pier. The bar should be about 3 ins. wide by 1.18 ins. thick. At the lower end it terminates in a rabbet, parallel to the props. It carries tongues 2.36 ins. wide underneath, and serving as guides. Each tongue has a hole for a pin to prevent the bar from rising. The tripper is so made as to lower the first shutters, one by one, and the later ones as many as four at a time. The guides of a tripper are two iron rods, parallel and horizontal, 4.92 ft. long by 1.57 ins. in diameter.

The whole is so arranged that the tongue, held laterally by the two rods of a guide, is raised 0.40 in. above the girder. A guide is placed about every 13 ft. The tripper is carried on bronze rollers $8\frac{1}{2}$ ft. apart, or twice the width of a wicket. The tripper extends about 9 ft. into the abutment. It enters through a sheet-iron gate. Behind this gate is a vertical roller which directs the bar against the pinion of the windlass. A rack at the end of the tripper engages the pinion of the winch-shaft, and is held in place by vertical rollers.

Maneuvers.—Raising the wickets may be performed from a boat or bridge by the use of a winch. If from a boat, it is placed at right angles to the current and above the abutment. It is fastened at the stern. The winch is placed a little aft, and the rope pays out through

a pulley in the bow. The wickets on the weir are raised first. The bow of the boat is placed opposite the first wicket and in line with its axis. The lock-keeper seizes the handle of the wicket with a boat hook. This is an iron rod 8 ft. long and $1\frac{1}{8}$ ins. in diameter, fastened to a wooden handle 13 ft. long and terminated by a hook, 2 ft. above which there is a ring. A rope about 50 ft. long is tied in this ring and is wound at the other end around the drum of the winch. When he seizes the handle and then turns the winch, the horse rises against the sill and the prop is finally set in the hurter. The pull should not be too nearly vertical. The proper angle is 45°, and the boat should be anchored at a proper distance to secure this angle. To be sure that the props are in place, a man below pushes the wicket forward with a pole. When this man feels the shock on the prop, he notifies the keeper, who orders the winding stopped.

The preceding operations are the only ones necessary when the axes of rotation and the flutter valves are so arranged that the wicket is raised automatically by the current. Otherwise the pressure on the chase is greater than on the breech, and if the current is swift it is necessary to pull on the chase with a boat-hook. When the pier is reached, all the wickets of the weir remain swung, and the river flows on without interruption while the pass is being closed. The wickets of the weir are then closed.

If a foot-bridge is used it must first be raised, as described in the case of Poirée trestles. The lock-keeper then brings all the props against their hurters by fastening the breech chains of the wickets to the drum of the winch and winding in. An assistant, in a skiff below the dam, sees that the props are properly in place.

When the wickets are swung the lock-keeper fastens the chase chains in the chain stops of the trestles, keeping the wicket a few degrees out of the horizontal. To right a wicket the winch is placed immediately opposite, and the truck carrying it is fastened to the trestles by hooks. The breech chain is lifted from its stop and wound backward around the small drum of the windlass. The chase chain is attached to the large drum and wound in, and the wicket straightens up into place. In order that the wicket may not be driven too violently into its place, the tightening of the breech chain must not be neglected.

To lower a wicket when the dam is provided with a tripping bar, the dam-tender turns the windlass until all the wickets are lowered

on the floor. He then draws the bar back to its original position, in readiness for the next operation. If the bar is out of order, or if the dam is not provided with one, and there is no foot-bridge, the boat is placed about 22 ft. above the wicket and parallel to the current. An assistant pulls the chase up stream with a boat-hook, so as to take the pressure off the prop. Another assistant in a skiff pulls the prop from its position with a boat-hook.

If there is a bridge, the chase chain is made fast to the windlass and the wicket is drawn up stream slightly. The prop may be then pushed out of place. When the wickets are all lowered, the trestles are also lowered. More recent forms of hurters permit the wickets to fall without pushing the prop sideways. This is accomplished by pulling up stream on the wicket until the prop drops out of the part of the hurter in which it has rested into a part having an open channel. Then, by releasing the pulling chain, the wicket will fall. This method is in use in this country, but it is believed that fully as good results would be attained, at least on the smaller rivers, with a properly constructed tripping device, with the additional advantage that the wickets could be thrown after ice had formed against the dam, it not being necessary to move the wickets up stream before lowering. There are many times when the dam has to be lowered too soon on this account, and much damage is done to loaded barges by lowering the water in the pool above.

Port à L'Anglais Dam.—The Port à l'Anglais dam, located just above Paris, is one of the most complete. It consists of a lock, a navigable pass, a weir and a sluice. The lock is on the left bank of the river. It is 689 ft. long, and 52½ ft. wide inside. The inside length is 590 ft. The water on the lower miter-sill is always 6½ ft. deep. The lock receives two rows of boats 25½ ft. wide. The old navigable pass is 179½ ft. from the exterior of the lock to the first pier. This portion of the dam is closed by 42 Chanoine wickets, each 9 ft. 10 ins. high by 3 ft. 11 ins. wide, with a space of 4 ins. between each. The sill of this pass is 6.65 ft. above the lower miter-sill of the lock. It is operated by a boat and a tripping rod. The weir is 124¼ ft. from pier to pier. It is closed by 27 wickets, each 6 ft. 7 ins. high by 4 ft. 3 ins. wide, after the pattern of M. Chanoine. A foot-bridge of 27 trestles, supplied by a rolling windlass, operates the wickets.

The sluice is $94\frac{1}{4}$ ft. from the pier to the abutment on the right bank. It is called the new navigable pass. Its sill is 4.26 ft. above the lower miter-sill and 2.33 ft. below the sill of the old pass. The upper pool varies from 12 ft. 2 ins. to 13 ft. 5 ins. above this sill, and as much as 9 ft. 10 ins. above the lower pool. The sluice is closed with Chanoine wickets 9 ft. 10 ins. high by 3 ft. 11 ins. wide. The wickets are modified in some ways to sustain the great lift. With a weight of 13 000 to 15 000 lbs. against the upper surface of each wicket, they must be made as narrow as is consistent with the stability of the horses. They are made of two 8-in. x 12-in. stiles, 12 ft. 8 ins. long, connected by four transoms and strengthened by iron straps and bolts. They are made water-tight by tongued and grooved planks nailed between the transoms. A space of 4 ins. is left between wickets to prevent interference, and this may be closed in one of several ways already discussed.

The La Mulatière Dam on the Saône, at Lyons.

The most advanced ideas, as applied to the general details of construction of a wicket dam, may probably be found in the dam about to be described. Its designer, M. Pasqueau, not only changed the methods theretofore in use for maneuvering wicket dams, but also made radical departures from established custom in constructing the various parts. He doubled the span of the trestles and suppressed their axle, as well as made numerous smaller improvements; and he applied a new kind of hurter or resting shoe for the prop of the wicket, by which it was made possible to lower the wicket without the use of a tripping bar. This invention has since had wide application in the United States, on the Great Kanawha and Ohio rivers.

Conditions to be Met.—The movable dam constructed at La Mulatière, 1879, is located at the junction of the Saône and Rhône rivers. Owing to the peculiar condition to be met, all dams theretofore known or proposed had been rejected. These conditions were met by the system proposed by Pasqueau and carried into effect in this dam. The conditions were that the Rhône, a torrential stream, which rises and falls very rapidly, nearly always forced back-water into the mouth of the Saône, and that consequently the rise came from below the dam instead of from above it. So that the pass must remain closed until the water of the Rhône reached the level of the upper pool. The dam

must then be opened very rapidly, to prevent the overflow of the foot-bridge. It must also be closed rapidly, to prevent the level of the upper pool from falling too low by reason of the subsiding of the Rhône. It is necessary to keep this dam at the constant level of 8 ft. on the sill, as the obstructions to be flooded are so near the dam. The dam is within 1 500 ft. of the St. Etienne Railroad Bridge, and the large and heavy freight boats navigating the stream must make a sharp turn between the bridge and the dam. Hence piers in the river would have been dangerous. Moreover, the dam had to be built with a view to sustaining great floods in the Saône, and to retaining a pool 13.1 ft. above the sill of the pass.

Description.—Modified Chanoine wickets are used, but the feature of the La Mulatière dam is the double-stepped hurter of M. Pasqueau. By the use of this hurter, the foregoing conditions were satisfactorily met. The tripping bar was done away with. In front of the usual step (called the resting step) the hurter was provided with a second step (called the sliding step). The face of the sliding step is vertical and forms an acute angle with the axis of the runway. Iron wickets are used. Wood lasts only ten years. The panels are 14.3 ft. by 4.6 ft. They are formed of two bars of U-iron $7\frac{1}{4}$ ins. by $\frac{5}{8}$ in. and 2.95 ft. apart. They are covered by $\frac{3}{16}$-in. plate-iron, projecting 10 ins. beyond the uprights, supported by braces and stiffened by angle-irons put on the edges. A flutter valve 5 ft. by 3 ft. is built into the chase of each wicket. It is held in place by a bell-crank and operated by a cane-headed pole from the bridge.

The ordinary journal boxes of the horse are not used. The lower axle of the horse is replaced by a steel journal box having three checks into which the lower eyes of the uprights of the horse of the adjacent wickets fit. They are held in place by $2\frac{3}{4}$-in. bolts. The sill is of cast iron, from $1\frac{1}{4}$ to $2\frac{1}{2}$ ins. thick, and lasts as long as the floor. A steam windlass is used in maneuvering the wickets. The time required to lower the whole dam is $4\frac{1}{2}$ hours, and to raise it 8 hours. A wide-span service-bridge is used, with trestles 9.8 ft. apart. The trestles are 22.3 ft. high, and when down they superpose in only three ranks. The axle of the old-style trestle is superseded by pin connections with the journal boxes on the floor. The bedding trench is thus reduced from 4 ft. to 28 ins. in depth. Two axles at the top of each trestle enable the adjacent sections of flooring to lie end to end, and decrease the

depth of the trench. The windlass carries a guiding bar, which lowers each section of floor, without shock, and holds it firmly in place while the trestle is being lowered. The trestles are symmetrically built in the form of a double St. Andrew's cross and possess great rigidity. They do not silt up as badly as those in which the up-stream leg is vertical. The raising of the wickets is done as in any dam. The dam-tender pulls on the breech chain until the prop falls into the resting step. He then slackens the chain and rights the wicket. To lower the wicket, he draws in the breech chain until the wicket swings, and continues to draw in until the prop falls into the sliding step. He then pays out the chain by the brake on the windlass. The prop automatically slides obliquely toward the runway and into it, and the wicket falls without shock.

The first advantage claimed for this hurter is that it obviates the use of a tripping bar. The greatest width of pass that has been operated by the use of a tripping bar is 160 ft. Any width desired may be given to the pass if this hurter is used, each being complete in itself. The pass in this dam is 340 ft. wide, with no piers in the stream.

Kanawha Dams.

The system of movable dams on the Great Kanawha River, the last of which is now nearing completion, furnishes the only example of its kind in this country. The description of this improvement, written by the engineer in charge, Addison M. Scott, M. Am. Soc. C. E., and published by the Government, is abridged and given below.

General Description.—The movable dams are of the Chanoine wicket type, operated from trestle-service bridges. In general features they are all alike, and are divided into pass and weir. Dams Nos. 4 and 5 were completed and put in operation in 1880, and were the first movable dams in connection with slack-water improvement built in America. Dam No. 6 was completed in 1886. Nos. 7 and 8 were completed during the season of 1892, and 9 and 10 in 1897. No. 11 is nearing completion.

The experience with movable dams on this river has, on the whole, been very satisfactory. They are easily and rapidly maneuvered, the expense of operation and maintenance is but little, if any, more

than with fixed dams, and they prove highly satisfactory to the river interests.

Advantages Over Fixed Dams.—The movable dams are kept up whenever there is not water enough in the river for coal-boat navigation and down at other times. Their advantages over the ordinary fixed dams, for a river like the Great Kanawha and having a similar commerce, are decided; furnishing the benefits of the usual slack water without its most serious drawbacks. With fixed dams everything must pass through the locks; with them navigation is entirely suspended too, when the river is near or above the top of the lock walls. With movable dams the locks are only used when the discharge of the river is so small as to make them necessary. At all other times they are down, practically on the river bottom, out of the way and affording unobstructed open navigation. This is of great advantage to all classes of commerce, and is particularly so with coal, transported as it is, and empty barges returned in "fleets" of large barges. More barges can, of course, be taken by a towboat, and much better time made by all kinds of craft in "open river," when there is water enough for such navigation, than when the stage or discharge compels the use of the locks. The movable dams being down in high water, there is comparatively little difficulty in protecting the banks about the works from scour. In this respect they also have considerable advantage over the fixed dams.

Modifications, Cost of Operating, Etc.—Experience with the dams has naturally suggested improvements, and the last ones completed have considerable advantages over those first built in strength and durability of construction, facilities for rapid maneuvering and cost of operation and maintenance.

The average cost of operating and maintaining one lock and dam has been $2 515 per year. This covers wages, supplies, repairs, including considerable addition to the rip-rapping, and all expenses connected with the work. The entire cost during five years of repairs on one dam proper and on all of its apparatus, including paints, one of the principal items, has been something less than $250, or an average of $50 per year.

These dams are put up by four or five men in from seven to twelve hours; the usual time being about eight hours. They are lowered with the same force in about two hours. No material

difficulty has ever been met with in any of the maneuvers. Four men are employed regularly at each work, the same as at the fixed dams. In raising and lowering the dams, one or two extra men are often hired.

Maneuvering the Dams.—The operation of raising and lowering the dams may be briefly described as follows : In raising the pass the bridge is first put up trestle by trestle, beginning at the lock. As the trestles come up, and with them the aprons that make the walk, the rails forming the connections and the winch-track are placed. In raising the trestles the winch is used by means of a small top-crane and sheave. After the bridge is up the wickets are pulled up one by one with the winch and wicket chains until the props drop into the hurter seats. The wickets are not erected or "righted" as fast as pulled up, but left "on the swing" (*en bascule*), that is, with the horse erect, the end of the prop in the hurter seat and the wicket in a horizontal position at the top of the horse. In this position the water passes freely under the wicket. If righted as fast as pulled up the head of water becomes so great that the last wickets cannot be safely handled with the winch. After being put on the swing clear across, they are all rapidly righted. This is done with the drum and brake on the winch and wicket chain, the butt of the wicket being held against the pressure of the water and let against the sill without shock. In lowering the pass the wickets are pulled up stream a few inches with the winch by a simple line and grab connection at the top of the wicket. This carries the foot of the prop out of the seat into the descending channel of the hurter, when the grab is disengaged and the wicket falls. After the wickets are lowered, the bridge is put down. The maneuvers briefly described above refer particularly to the navigation pass. The weir is maneuvered on the same general plan, but the weir wickets, being smaller than those of the pass, can be raised or lowered, put on the swing, or righted with full head whenever desired. The maneuver of the weir when the dam is up is governed by the stage or discharge of the river, it being kept wholly or partly raised as required to regulate the surface of the pool. A pass wicket, for reasons given above, is never lowered or swung unless the whole dam is to go down.

Telephone Line, Equipments, Etc.—Concert of action is necessary in maneuvering the dams and regulating the pools, and the different

works are connected with each other and with the central office at Charleston, by telephone. The line is also extended to Kanawha Falls to give notice of floods, and daily communication by mail, and by telegraph when necessary, is had with Hinton at the mouth of the Greenbrier, 60 miles above the Falls.

A light service boat, furnished with derrick, capstan, and cabin, is required at each movable dam to assist in the maneuvers and to transport bridge rails, tools, etc. A complete diving outfit is also necessary at each.

On the bank, in addition to the houses for the men, a drum house and tramway to handle apparatus and tools, a carpenter shop, blacksmith shop, and a storehouse are required. Such buildings, except the drum house, are in use at the fixed dams as well. All of the ordinary repairs are made by the regular lock hands.

Lock and Dam No. 7.—A brief description of one lock and dam will suffice for all. It is located 44 miles from the mouth of the river and is founded on bed-rock and hardpan, a tough, indurated clay, varying in depth from $3\frac{1}{2}$ to $8\frac{1}{2}$ ft.

Lock.—The lock is 342 ft. long between quoins, with a clear width of 55 ft. in the chamber. The total length, not including guard cribs, is 411 ft. The walls, including concrete foundations, are from 27 ft. to 31.75 ft. high; they are uniformly 20 ft. above the top of the miter-sills. The maximum lift, when dam No. 8 is up, and the pools are full, is about 8 ft.; with No. 8 down, the lift in low water would be about 10 ft.

The stone used is yellowish and bluish gray, medium and fine-grained sandstone (probably the "Morgantown" and "Mahoning") from three quarries along the river from one to seven miles above the site. It weighs about 150 lbs. per cubic foot, and the crushing load of 2-in. cubes varies from 25 000 to 46 000 lbs. The chamber faces of the walls are of pointed-face ashlar, and the other faces generally, except the back of the land wall, of rock-faced ashlar. The chamber corners, quoins, sills and coping are dimension stone, bush-hammered. The interior of the walls and the back of the land wall and wings were classified as "backing."

The gates are of white oak, built without heel or miter "posts"; the main beams running through and the ends and center made solid

by filling blocks, assembled with horizontal and vertical bolts and keys, and spaces planked. They are suspended at the heel on steel gudgeons, and by top fastenings and anchorage, all below the level of the coping. Each leaf weighs complete about 37½ tons. The lock is filled and emptied by valves in the gates, each leaf having five cast-iron valves hung horizontally in a wrought frame. The net filling and emptying areas are each close to 68 sq. ft. The valves are maneuvered by racks and pinions and the gates by spars and capstans. The lock was built under a contract that covered the lock complete, except the gates. It included coffer-damming, pumping and bailing, and the furnishing of all work and of all materials, except the irons built in the masonry, these irons being supplied by the United States, and placed by the contractor. The aggregate of the contract was $160 630.24.

Dam.—The dam is of the Chanoine wicket type, operated from a trestle service-bridge. It is divided into two main parts, the navigation pass and the weir, or into four parts beginning at the lock, viz., the navigation pass, center pier, weir and abutment.

The pass foundations all rest on concrete, the latter extending to bed-rock under the upper and lower or exterior walls, and at the wicket and trestle anchorage, and to hardpan elsewhere. The foundations are 50 ft. long, up and down stream, between neat line of walls. The surface or apron of the pass is entirely of masonry, except the wicket sill and the timbers for the horse and trestle boxes.

The pass is 248 ft. wide. It is closed by 62 wickets spaced 4 ft. between centers. The wickets are of oak with pine panels, framed and ironed. They are 3 ft. 8 ins. wide, the space between them being 4 ins. wide and 14 ft. 0⅛ in. long. The axis of rotation is 6 ft. 10 ins. from the butt of the wicket, and 5 ft. 11 ins. vertically above the top of the sill. The tops of the wickets stand 13 ft. vertically above the sill. The inclination with the vertical is 20°, and the lap on the sill is 5 ins. These wickets are a few inches longer than any before built on the river.

The service-bridge of the pass is made by thirty wrought-iron trestles, with attached aprons for walk and connecting rails. The trestles are 8 ft. apart between centers. The floor of the bridge is 16 ft. 9¼ ins. above the center of the bottom axis of the trestles and 2 ft. 6 ins. above the top of the wickets or normal pool level. The trestles

are connected by chains for use in raising, the aprons forming part of this connection, and have forged stops in which to fasten the wicket chains. The wickets and bridge are anchored by $1\frac{3}{4}$-in. rods and cast discs, built in the foundations, spaced 4 ft. apart for both wickets and bridge.

The masonry of the down-stream wall of the weir extends to bed-rock, the remainder of the foundations resting on the hard-pan. The space between the upper and lower walls is filled partly with concrete and partly with clay and gravel, the concrete being used about the anchorage and immediately under the surface masonry.

The weir is 316 ft. wide, closed by 79 wickets set 4 ft. between centers. The wickets are 3 ft. 9 ins. wide (the space being 3 ins.), and 9 ft. $2\frac{1}{8}$ ins. long. The axis of rotation measured on the wicket is 4 ft. from the butt, and vertically 3 ft. $4\frac{3}{4}$ ins. from the top of the sill. The top of the wicket is $8\frac{1}{2}$ ft. vertically above the sill. The inclination with the vertical is 20°, and the lap on the sill is a fraction less than 4 ins. These weir wickets are from $1\frac{1}{2}$ to $3\frac{1}{2}$ ft. longer than at the older dams on the river.

The weir service-bridge is made by 39 trestles, spaced, except at ends, 8 ft. between centers. In general form of construction it is like the pass bridge, the trestles having attached iron aprons, connecting chains and stops for wicket chains, etc.

The upper surfaces of the weir foundations of the Great Kanawha dams are all a little above natural low-water mark. On account of this, in recent construction, beginning with Dam No. 6, the surface is made entirely of masonry (except the upper guard stick and wicket cushions, both easily renewed), and the trestle boxes, wicket sill and hurters are fastened directly to the coping by wedge bolts. The wicket sill is of cast iron, made in sections, with the horse boxes attached. The sill is anchored by rods and discs.

The foundations and masonry of the dam were built by a contract that covered the work complete, ready for the wickets and trestles. It embraced coffer-damming, pumping and bailing, and the furnishing of all work and of all materials, except the iron built into or attached to the work, these irons being furnished by the United States and put in place by the contractor. The aggregate of the contract, as above, is $118 215.

The estimate for the lock and dam complete is as follows:

The lock	$160 630	
Irons built in masonry of lock	1 093	
Lock gates complete	7 800	
		$169 523
Foundations and masonry of dam	$118 215	
Iron work in anchorage and fixed parts of dam	5 500	
Iron work in movable parts of dam	12 700	
Wood work of wickets	2 350	
Diving apparatus and service boat	1 300	
		140 065
Land at site, buildings, engineering, superintendence and incidentals		34 012
Total		$343 600

The Ohio Dams.

The Chanoine wicket dam with Pasqueau hurters at Davis Island, a few miles below Pittsburg, affords the sole example of a wicket dam with wide pass in America. Originally the movable part consisted of a navigation pass 559 ft. wide, and three weirs, 224, 224 and 216 ft. wide, respectively. Later, the first weir was shortened by the construction of a drift-gap 52 ft. in width closed by bear-trap gates, and the pier between it and the pass removed, so that now the navigation pass is 719 ft. wide. The description here given is compiled from one written by the engineer in charge, William Martin, in 1886, and published in *Engineering News*.

General Description.—The Chanoine dam at Davis Island is the first of a series of movable dams devised for the radical improvement of the Ohio River. It is located 5¼ miles below Pittsburg, and is designed to make slack water between the dam and Lock No. 1, on the Monongahela River, and on the Allegheny River to Thirty-sixth Street, 2½ miles above its mouth.

The lock is located on the north side of the Ohio. The distance between the gates of the lock is 600 ft., and the total width of the lock is 110 ft. The noteworthy difference between this and ordinary locks is in the employment of rolling instead of swinging gates, and in the construction of recesses for the reception of the gates when

open. These recesses, or slips, are built towards the shore, from the lock, a distance of 120 ft. The total length of the river lock wall is 689 ft. The wall is 11 ft. thick, and has a height of 17 ft. above and $2\frac{1}{2}$ ft. below the gate sill, making a total height of $19\frac{1}{2}$ ft. The land wall (including the development of the recesses for the gates) is 1 169 ft. long.

The movable dam begins at the river lock-wall, at a point 100 ft. above the lower lock-gate, and extends to the abutment on Davis Island. The dam is 1 223 ft. long, and is composed of 305 wickets, divided into four sections. The main sills of the weirs have the following reference to that of the navigable pass. Weir No. 1, 1 ft. above, No. 2, 2 ft. above, and No. 3, 3 ft. above. This stepping of the sills was necessary in order to make the profile of the dam conform to the natural bed of the river.

Dam.—The floor of the dam is a framed structure composed principally of 12 x 12-in. white oak timbers, framed in such a manner as to form a rigid combination. This framework was built in the foundation at the proper height, and the concrete built up around the timbers, thoroughly imbedding them. On the foundation thus prepared, and composed of the concrete anchorage and frame structure referred to, the dam is secured. The wicket anchor bolts pass up through the timber structures, and through a cast-iron box called the "horse box." This box forms the fastening for the lower axis of the horse, and is the chief connection holding the dam in position. Each wicket is composed of a horse, a prop and a panel, or shutter. The lower axis of the horse is secured to the horse box; the upper axis is attached to the panel near the center, around which the panel is free to rotate. The wickets, when in position, are inclined down stream at an angle of 20° with the vertical, the lower end or breech resting against the main sill, while the upper end is supported at the upper axis of the horse by the prop, which rests against a cast-iron socket, secured to the foundation and called a "hurter." Thus the dam is formed by a series of wickets extending across the river. Each wicket is 3 ft. 9 ins. wide, with a space of 3 ins. between them. This space is to prevent the wickets from becoming foul with each other, which would prevent their free movement. The spaces, during very low stages of the river, can be closed, if necessary, thus saving the water to maintain the pool at its full height.

The arrangement by which each wicket is held in position and lowered to the bed of the river at will may be described as a sort of folding joint. All parts when lowered assume a horizontal position, and lie below the main sill, insuring safety from steamboats or floating objects.

The navigable pass is worked by a maneuvering boat, made of steel. The wicket winch is located in the center of the boat, and the line from the winch, by which the wickets are raised, changes its direction by passing over a steel sheave, mounted at the bow. Eight outriggers, suspended on the side of the boat, serve a double purpose, forming a platform for the workmen and keeping the boat far enough from the face of the dam to permit the breech of the wicket that is being raised to swing past the sheave to its seat against the main sill of the dam. On the outer ends of each of the two forward outriggers a buffer $4\frac{1}{2}$ ins. thick, 12 ins. wide, and $6\frac{1}{2}$ ft. long, is fixed, and rests against the wickets raised. These buffers have a high and low position, the former for working in low water and the latter in high water. This is for the purpose of keeping the point of bearing on the wicket below the axis of rotation, to prevent the wicket swinging when the pressure required to raise a wicket is brought upon it. The line from the winch in the boat has a maneuvering pole attached to its end, and the end of this pole has a hook with which the operator grapples the wickets. The location of the wickets sought can be almost definitely fixed by the one last raised; rarely has the hook to be cast more than twice.

In lowering the dam it is only necessary to catch a wicket at the top, and draw it forward until the prop drops off the inclined step on the hurter, the wicket is then released, and the pressure of water against it forces the prop into the downward channel of the hurter, when the wicket falls gently, and without any shock, into its position in the bed of the river.

A second dam of this character is now under construction on this river, some 25 miles below Pittsburg. It is to have a navigable pass 600 ft. long, closed by Chanoine wickets, operated from a maneuvering boat, and three weirs of the old style bear-trap, each 120 ft. long, separated from the pass and from each other by piers in which are located the maneuvering valves. The use of compressed air for creating an initial head in raising bear-trap gates will be tried experimentally here, and probably lead to a plan for starting this sort of gate without providing means for creating an artificial head.

Remarks on Wicket Dams.

Tripping Bar.—Had M. Pasqueau given the same amount of study to improving the tripping bar that he expended to encompass its abandonment, it is probable that there would be to-day wicket dams which could be lowered in ice and drift from the shore.

On the 27 wicket weirs of the Meuse and the 29 dams between Paris and Auxerre, which have been in operation for 20 or 25 years, there has rarely been an injury to the tripping bars, although they have occasionally caused slight delays in opening, but never a serious impediment to the complete lowering of the dams.

The ability to rapidly drop the wickets from the shore by simple mechanism after the formation of ice or the accumulation of drift is undoubtedly to be placed first among the advantages of the Chanoine system, and, while it may not be practicable to accomplish it on wide openings by the same means adopted on those of less width, yet the same result may, in the author's opinion, be attained by the application of different ideas. The tripping bars in use lie on rollers on the masonry floor, and have projections which successively engage with and move the props of the wickets sidewise when the bar is put in motion by machinery on the pier or lock-wall. The objection has been raised that the bars at times become fouled by stones, timber, etc., and refuse to act. They cannot be used for wide passes, because, as it is necessary for the bar to move about 3 ins. in order to throw a prop out of place, it is plain that the number of projections will be limited. The custom is to first throw a few wickets separately, then by twos, and then by threes, and so on, the head becoming rapidly reduced after a few wickets have been lowered. In this way quite a length of dam can be thrown with a single bar, and, as two bars can be used on each opening, operated from machinery at each end of the opening, it is possible to apply this style of bar to weirs up to 200 or possibly 300 ft. in width; but even if they could be made sufficiently powerful to throw very wide openings, the objection of their becoming clogged still remains, and the author is led to suggest a possible solution in which this objection, at least, will have no weight.

This solution lies in placing the tripping apparatus in a practically water-tight conduit in the masonry, which conduit may be pumped out or flushed at will. Without going into details here, it may be stated that it is believed that suitable apparatus can be devised

and maneuvered from the lock-wall or pier to successively throw all the wickets as rapidly as desired.

Prop and Horse.—The present construction of prop and horse renders a wicket unstable, and the oblique traction necessary in maneuvering makes it impossible to place them adjacent. This may be obviated by a more rigid connection between prop, horse and wicket. The necessity for sliding the prop sidewise out of the hurter in lowering causes this trouble, and a method should be adopted which will permit the releasing of the prop without moving it sidewise. With such an arrangement a prop after the plan of that proposed in the dam of Janicki, a ⊐-shaped construction, would be best. A folding prop, hinged at the bottom and having a joint below its head, has also been proposed.

Hurters.—There are in use: the original Chanoine or Thenard hurter, which has a seat against which the prop rests, and from which it is pushed sidewise by a tripping bar into a channel, down which it descends; the Pasqueau hurter, in which the wicket is pulled up stream until the prop drops on a lower step which, by an inclined wall, leads to the descending channel; and the Scott hurter which accomplishes the last result by shunting the prop into the descending chute by an inclined surface as it is pulled up stream.

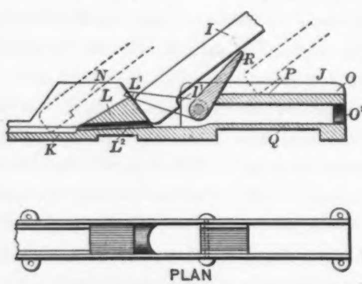


Fig. 3.

A hurter designed by the author and his brother (Fig. 3) has been in use on a trial wicket on the Great Kanawha for the past 10 years, where it is said to work satisfactorily. In this the wicket is drawn up stream, as usual, until the prop falls over a tongue hinged to the hurter, when, by releasing the wicket, the position of the tongue is reversed by the descending prop, so as to cover the prop-seat and carry the prop over. This admits of a rigid prop-head and requires only a very narrow hurter with one slide.

The shunting of the prop sidewise may also be effected by a wedge-shaped piece attached to the side of the foot coming in contact with a

lug, cast on the hurter, as the wicket is pulled up stream. The fact that the wickets must be pulled up stream against the great head of water, in all of these forms, except the original, in order to lower the dam, is a serious drawback to their use. The other fact that in all, including the original and excluding the trial one mentioned, the prop must move sidewise in order to strike the downward slide, is also an objection having weight. A hurter should be so designed that the pressure of water on the wicket would assist in releasing the prop rather than have to be overcome when the time comes to lower the dam, and that no lateral movement of the prop would be required or even possible. The solution of this problem in connection with a suitably constructed tripping device can, in the author's opinion, be satisfactorily attained with very simple appliances.

Conduit Tripping Devices.—Against his former intention the author presents the following suggestions:

Conduit.—Under the line of the feet of the props, when standing, is a small tunnel or conduit reaching the whole length of the opening to be closed, and connecting at its ends with the upper and lower pools, and also connecting with vertical wells in the masonry. By the opening of valves at each end of the conduit, when there is a difference of level in the two pools, a current can be passed through it for the purpose of keeping it clean. By closing the valves, the contents of the conduit may be exhausted, when desired, by a pump located in one of the wells mentioned, so that it may be entered for inspection.

Wheel Hurter.—Shafts of suitable size, of such lengths as may be desirable, and having bearings at intervals, are placed in the conduit, and on these shafts are keyed flat-faced wheels called hurter wheels, so spaced as to be the same distance between centers as are the wickets. The top of each of these wheels projects through a slot in the covering of the conduit immediately down stream from the foot of the props, so that these members may rest directly against the wheels. One or more cog or ratchet wheels are also keyed to each shaft, which when engaged with suitable teeth on the tripping bar, which bar is also in the conduit, will prevent all the wheels from turning. Each shaft will have as many hurter wheels as it is desired to throw wickets simultaneously, so that the disengaging of the teeth from the ratchet or cog wheels will lower as many wickets as there are hurter wheels on that shaft, by the pressure of the prop turning these wheels and being car-

ried over their tops. The shaft, of course, must be so placed as to be slightly below the line of pressure through the prop, so that when the teeth of the tripping bar are removed from the cogs, the wheels will turn; but it should not be low enough to bring an unnecessary strain on the shaft when locked. The cog wheels will be hooded so as not to show above the surface; and as neat a fit as practicable will be made about the hurter wheels so as to, as nearly as possible, make the conduit water-tight when being pumped.

Sectional Tripping Bar.—The tripping bar is made in sections connected together with links which slide in slots near the ends of the sections. It is forced to travel in a direct line by suitably constructed guides and rollers. One end-section has a rack which gears into a pinion on a vertical shaft located in the masonry well, above mentioned, the top of which has suitable gearing for transmitting power. The bar sections correspond in length to the shafts, and, when placed abutting each other, their teeth, which are preferably on their top side, are in their several cog-wheels. By turning the capstan at the masonry, the first section will move toward it, and the teeth will be released from the cog-wheels. This will allow all the wheels on the first shaft to turn and thus throw the wickets. The link connecting the first and second sections will then move the second section by the continuation of the winding at the capstan, and its teeth will in turn be drawn out of the cogs, at which time the third section will be started by the tightening of its link. A continuation of the winding will release all the wheels and throw all the wickets. The bar is then returned to its original position by reversing the movement of the capstan, the links sliding in the slots and permitting the several sections to push each other. The teeth and cogs are so shaped that it is impossible not to engage with each other. An indicator will show when the bar sections are all in their proper places. The sections are so constructed that no foreign substance can lodge in the open space between them when they are being removed.

Lever Tripper.—With this method the old-fashioned hurter is used. Suitably pivoted in the conduit are upright levers which project through the conduit covering alongside the props. The moving of the long arms of the lever in one direction will cause the short end to press against the bottom of the props and push them out of the seats into the descending slides. The levers can be set and connected to

throw simultaneously as many wickets as desired. Lugs on the tripping bar are brought in contact with the levers in succession to accomplish their movement.

Lifting Tripper.—Immediately under the foot of each prop is a vertical pin. The bottom of this pin is in the conduit, where it is held rigidly in place by a casting a few inches above the end. When the tripping bar is set in motion, suitably shaped projections must pass under these pins, and this they can only do by raising the pin and with it the foot of the prop, which is lifted out of its seat. The wicket is thus deprived of its support and falls. The hurter for this device need have but one slide, and the prop-head may be rigidly attached to the wicket. As many wickets as desired may be lowered simultaneously by this method, by connecting the bottoms of the pins. Levers may also be used in connection with the pins if it is desired to increase the power. Arrangements for the reduction of friction, and the shutting out or reduction of leakage when desirable, are to be made in any conduit device; in the last mentioned the pins should be of material which will rust very little.

Boulé Gates.

Original Form.—The two principal types of movable dam in use have been described, and other forms less known will now be taken up and considered in as little space as possible.

The first of these is the Boulé gate which has had a fair trial, in France, at Suresnes and Marly and other places, and in Russia, and is well liked. In the latter country the gates are mere planks 0.08 ft. wide, with pegs near the ends worked by hooked poles. This dam, invented by M. Boulé in 1874, consists in the substitution of the ordinary gates of hydraulic works for the Poirée needles. The Poirée trestles are used and all the mechanism of the Poirée dam, with the exception above mentioned. The gates are made to slide vertically between the trestles. They are raised and lowered by one maneuvering screw or jack, and are sent to the store-house by way of the service-bridge, either upon the car or carried by the assistants. The gates are made small enough to render them easily handled. They are attached to the hoisting machine by chains, which are constantly fastened to each gate, or by a pole or boat-hook, hooked into the handle of the gate; the latter being constructed like the handle of a Chanoine wicket.

The trestles must be built close enough together to sustain the weight without increasing their dimensions too greatly. The width from trestle to trestle should not exceed 3.28 ft.; hence, the width of the gates is the same as that of the trestles. The height of the gates should not be so great as to make them burdensome to handle. On this account each bay is filled with several gates, one above the other. The essential feature of this dam is several rows of rectangular gates arranged horizontally.

Maneuvers.—To open this dam the procedure is the same as to open the old-time stanches, that is, the top row is first taken away and afterward the succeeding rows. At the instant of raising, each gate will support a column of water whose head equals the depth of the flow over the top of the dam increased by the height of the gate itself, provided the gate be clear of the lower pool. If the gate is not clear of the lower pool, the head will equal the total lift of the dam, and will consequently be very small. The upper row of gates sustains a less load than the lower ones. Hence it is more easily raised. When this row is taken out, the level of the pool drops, and the second row is taken out under about the same pressure as the first. Or, if the discharge above is enough to keep the level of the pool at its original height, the lower pool will be raised, with the same result. The lowest row of gates will be under water on both sides, and the pressure will be neutralized. The maneuvers of these gates are always easy, if the dam is long enough to prevent a great overflow, and if the gates are small.

To close the dam the reverse order of the foregoing is used. The lowest row of gates is first let down. While the fall is slight, the next row will be put in place. It should be easier to close the dam than to open it, as the work will be done against a smaller head of water. The maneuvering is not all done at one time, but successively according to the amount of discharge, so that the duration of the maneuver, while considerable, becomes immaterial. If the river rises above its normal level, the gates are all removed and the trestles laid down. When the river recedes, the gates are replaced without allowing the stream to fall below the normal level of the pool.

Dimensions and Arrangements of Gates.—The breadth of the gates is determined by the distance between the trestles, and should not be greater than 3.28 ft. As the height of the pool increases, this width

should diminish. The height of the gates depends upon the depth of the pool, and the width and solidity of the service-bridge. The last element limits the hoisting power of the apparatus. In the high dams the trestles are stronger and closer together; therefore, the height of the gates may be increased and their number diminished. The height of the lower tier of gates may be increased as it is submerged and more easily raised. The total area of a gate should, as a rule, be from 10 to 20 sq. ft., and should not vary much from 15 sq. ft.

There is an advantage in having at the top of the dam a row of very light gates or boards which the dam-tender may place or remove by hand. They should be from 4 to 12 ins. in width, and quite thin, as the pressure is light. During low-water these are sufficient to regulate the surface of the pool. If one row of boards is not enough two may be used. If the board is 1 ft. high and 4 ft. long and the overflow is 0.66 ft. above them, then the load equals 280 lbs., and the board should weigh from 16 to 20 lbs. and be $\frac{7}{10}$ in. thick. Assuming a coefficient of 50% for friction, the force of 140 lbs. is required to raise it. If this is too much of an exertion, a lever can be used. The lower gates may be of iron, but are better if made of wood, They are then lighter and more easily repaired. The gates are made of planks, tongued and grooved, or joined with a double groove and false tongue of sheet-iron. They are also connected by a vertical assembling rod and rest their ends against two adjacent trestles.

If the gates are 4 ft. wide and 4.25 ft. high, each gate will have a surface of 17 sq. ft. If the head is 9.84 ft., the pressure will equal 62.5 x 9.84 x 17; that is, 10 455 lbs. Therefore the thickness should be 0.27 ft., and a thickness of 0.33 ft. would answer for a head of 13 ft. The gates are then no thicker than the needles ordinarily used. In opening the dam there is about the same amount of wood to be removed as in opening the Poirée dam. Allowing a coefficient of friction of 50%, a force of 5 227 lbs. would raise the gates under a head of 9.84 ft.

The trestles may be constructed with grooves of angle-iron from the sides in which the gates are to slide. Iron bars should be fastened to the edges of the gates, to diminish friction. To prevent jamming of the gates in the grooves, in case of warping, it is better to have the shoulder of the trestle open up stream, and to fasten the planks of the gates together by two angle or T-irons at the sides.

These rest against the upper trestle posts. This dam may be heightened at any time by the use of planks. If the trestles are not strong enough, they should be replaced. The trestles should be made with an excess of strength, with a view to heightening the dam if desired. The Boulé gates have been used at the deepest pass of Port à l'Anglais, at La Mulatière and in part of the Suresnes dam.

Summary.—The advantages claimed by the inventor for the Boulé dam over other systems are as follows:

1. It is simpler in design and construction than the Chanoine wickets.

2. The cost is inconsiderable, as shown at Port à l'Anglais. It shows a saving of 30% over the Chanoine wicket system. There is less linear surface necessary, thus saving in the cost.

3. The cost of maintenance is less than that of wickets.

4. The first cost is about the same as that of the Poirée needle dam.

5. The pool can be raised higher than with the Poirée dams, and much more easily.

6. The service-bridge can be replaced sufficiently high above the surface of the pool to be out of danger of floods. Consequently the dam can be opened in time to prevent overflow of the bridge.

7. A fixed weir is unnecessary, greatly reducing the expense.

8. Regulation is easy, and may be conducted without rushing.

9. It is easy to communicate the amount of discharge in the stream by telegraph or telephone to the dam-tender at the dam below, thus advising him of a probable rise.

10. On account of the even overfall along the whole length of the dam, the bad effects of scour and eddies are reduced.

11. The overflow carries all drift away, thus rendering this dam more sanitary than others.

12. It may be closed without waiting for the pool to fall below its normal level.

13. It is tight. The leakage is very slight, thus rendering it especially valuable for summer water power.

14. There is no submerged machinery to repair or to get out of order.

15. The maneuvers are performed easily and without danger.

16. The level of the pool may be raised by inserting boards at the top of the dam if it is desired to raise the pool only slightly; and by

adding to the height of the trestle if a considerable addition is desired to be made.

It is urged as an objection to this dam that it requires too long to maneuver it; but this has been claimed also as an advantage in that it prevents flushing. If this is not so, the system of escapements and of flutter valves obviates this objection. The time required to remove a gate is from two to three minutes in the top rank, and from five to six minutes in the bottom rank. But the last maneuver is rarely necessary.

The friction of the gates on the trestles is as follows: On a gate of

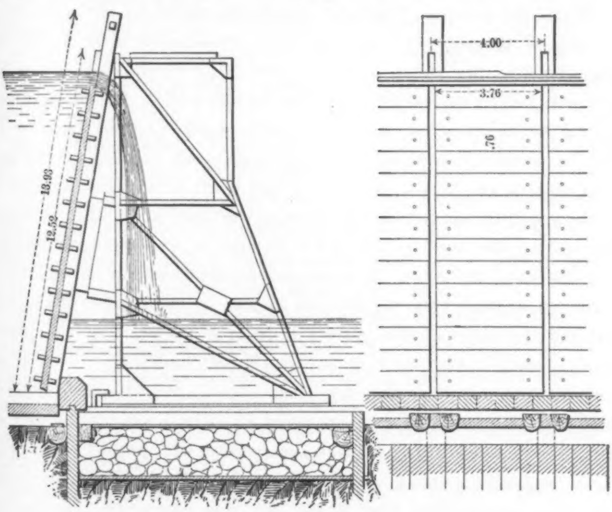


FIG. 4.

the upper rank, 1 770 lbs.; on a gate of the second rank, 5 391.25 lbs.; on a gate of the third rank, 5 570.33 lbs.

Experiments looking to the introduction of ball-bearing rollers have been made on the dam at Marolles. The gates were 3.52 ft. long and varying in height from 11.81 ins. to 19.68 ins. With a lift of 7.21 ft., the panels could be placed or taken out by one man with the greatest ease. A complete and interesting description of these experiments may be found in the "*Annals des Ponts et Chaussées*" for April, 1896.

Remarks on Boulé Gates.—M. Janicki, in 1876, applied this principle to the Moscow dams, in Russia, by replacing the gates with planks 0.8 ft. wide. These can be maneuvered without a crab, by a hooked pole. Pegs are placed near the ends which act as guides on the down-stream side, and handles on the up-stream side. Instead of resting the planks directly against the trestles, as in the Boulé dam, upright timbers, or needles, are placed against the sill at the bottom and against the trestles at the top, and these are made to support the planks. These uprights or posts are supported against the trestles, near the center of pressure, by a suitably constructed frame (Fig. 4).

While the method of maneuvering is simplified by the reduction of the size of the gates, the objection still remains, as in the Boulé dam, that the lowering takes place too slowly for rivers liable to sudden freshets; but by carrying the idea of Janicki a little farther and introducing another feature, the author believes an excellent form of dam may be obtained; applicable, at least, wherever needles can be used. This consists in placing the tops of the posts or uprights against the hook-ends of the escape-bars connecting the trestles. In lieu of the bracing against the trestles, the posts should be well strengthened with iron channels, bolted on the sides and reaching within an inch or two of the up-stream edges; the rabbets formed by the flanges of the channels and the edges of the posts will receive the ends of the planks, which should be slightly rounded, to prevent jamming. By stringing the planks on a rope as they are being placed, and attaching this rope to the proper post, the escapement of the whole bay will be easy and safe, because the turning of each escapement will permit one upright to fall, and with it will go one set of planks. With wide-span trestles more than one upright may be set on each escape-bar, because the boards should not be very long.

Camerè Hinged Curtain Dam.

M. Cameré, Engineer at Vernon on the lower Seine, devised a dam similar to that of M. Boulé, the only difference being that, instead of the Boulé gates, a wooden curtain is used. This curtain consists of narrow strips of wood, hinged together, and susceptible of being rolled up and lowered, by means of an endless chain passing around it like a theater curtain.

This dam is opened by rolling the curtain up from the bottom; whereas the Boulé gates are opened from the top, by removing the upper rank of gates. The dam is closed by dropping the curtain. The width of the curtains corresponds with the width of the Boulé gates. They are as long as the depth of the pool. The lower strips of the curtain are made thicker than the upper ones, in order that they may sustain the greater pressure of the water toward the bottom of the dam.

The curtains are maneuvered by means of a crab placed on the foot-bridge. The dam is supported by a series of Poirée trestles. The rolling or unrolling can be stopped at any place, thus regulating the opening as exactly as may be wished. This dam has been adopted at Port Villez, which is situated 145 kms. from Paris, on the Seine. It consists of two navigation passes and a weir, with a total length of over 700 ft.

Dam at Port Villez.—The following description is condensed from a report published by the United States Government: *

The flooring consists of a raised portion, forming the up-stream sill, united by a curved portion with a recess which holds the lowered trestles. The sill is 13.12 ft. below the upper pool. The recess protects the trestles from the keels of passing boats.

Trestles.—The trestles are planned so as to present the minimum of obstruction consistent with strength. The up-stream uprights have a small T-iron on their face, the projecting web of which serves as a guide to the curtain-bars resting on this upright. The bracing is calculated on the supposition that the pressure of the water is distributed over the whole height of the uprights, instead of being transmitted only at the top, as in the case of needles. A bracket, placed on the down-stream upright, serves to widen the service-bridge roadway, and allows two tracks to be laid; the rails serving as braces between the frames, and replacing the catches used in the older frames. The trestles are moved by means of flat iron bars, each in three parts, joined together, and having a joint at each extremity.

Lowering the Trestles.—When a trestle is to be lowered the joint of one extremity of a bar is pinned to the upper cross-bar of the trestle and the other extremity is made fast to a car, movable on the track on the service-bridge. This car is held by a chain, passed around the drum

* Un. Ex. 1889, Paris, p. 607.

of a windlass, the latter being held by another chain, made fast to the next pier or abutment. To lower the trestle, it is only necessary to push the car forward and pay out the windlass chain. When the trestle is lowered, the flat bar fixed to the car is detached and pinned to the side of the cross-bar of the following trestle still standing; the operation is repeated, and while the second trestle is lowered, the flat jointed bar connecting the two trestles folds together, forming a V, the unequal branches coming together between the two trestles without forming heaps like the chains. The trestles are lifted by reversing the operation.

Curtains.—The curtain is rolled or unrolled by an endless chain as follows: Each line of the endless chain, passing over the guide pulleys, forms two bights, one to the right and the other to the left of the curtain frame; the one passing around the curtain regulates the amount rolled up. To operate the curtain, the two lines of the chain of the down-stream bight pass over the chain pulleys of the windlass; the combined motion of these pulleys produces an elongation or contraction of the other bight.

The windlass for handling is mounted on a car rolling on the rails of the foot-bridge, to bring it in front of the curtain to be moved. When placed it is clamped to one rail of the track. On the other side a movable buffer on the upper part of the windlass rests against the curtain-frame, and resists its tendency to turn in the up-stream direction. The windlass carries two outside chain pulleys, corresponding to the curtain-frame guide pulleys. The lines of chains are put upon these, and maintained in their places by rotating stops which can be lifted to allow the chains to be taken off or put on.

The pulleys are keyed to shafts driven by the windlass gearing. The lower pulley may be engaged or disengaged. When engaged it turns in an opposite direction from the upper pulley, and its circumferential velocity is a fraction of that of the other. This being so, to roll up the curtain the lower pulley is engaged, and the upper pulley exerts an effort on its chain, while the lower pulley pays out its chain. On account of the difference of the velocities of the two pulleys a shortening of the bight passing round the curtain takes place, and the curtain rolls up. To unroll the curtain, the lower pulley is disengaged, its chain is made fast by a stop on the guide pulley of the curtain frame, the upper pulley turns, letting go the chain, the bight lengthens and the curtain unrolls.

The curtain frame is shipped on a special car carrying an inclined plane furnished with a windlass and chain. This car is brought in front of the curtain, and the screws fastening the curtain frame to the trestle are removed, so as to allow the former to turn around its journals. The windlass chain is hooked to the upper bar of the curtain frame, and the latter turns around its journals until it rests upon the inclined plane. Then, by the continued action of the windlass, it is hoisted upon the car by moving upon rollers fixed to the inclined plane. The curtain frame, thus completely separated from the trestles, can be carried off on the car. It is replaced by the reverse process. This manner of closing is also in use in the dam at Poses and part of the dam at Suresnes, described further on.

Remarks.—That the Cameré curtain could obtain a foothold and actually be built and operated on navigable rivers only proves that means for closing passes of moderate lifts have been very scarce. In the author's opinion, the dam does not possess a single good point. It is expensive, frail, easily worn out, unwieldy, regulates the pool from the bottom, and is therefore dangerous to the foundation, and its operation is both slow and laborious. Each curtain must be removed by a special car and taken ashore as soon as removed, and it must be unrolled and cleaned and hung up to dry on a special frame in the same position as in the dam; and their weight is 1 600 lbs.

The Dam at Suresnes.

The Suresnes dam, located just below Paris, was built by M. Boulé in 1885. It is one of the largest as well as most recent works of the Seine, and one of the best examples of movable dams in the world. It is made by the use of alternate bays of Boulé gates and Cameré curtains. The trestles of the pass are 19½ ft. high, and the gates 17 ft. high and 4.10 ft. wide. The dam supports a head of 10.6 ft. It is divided into three parts by two islands, Folly Island and Puteaux Island. The navigable pass is 238 ft. wide, and is located in the left arm of the river. In the right arm there is an elevated pass 206 ft. wide. Between the two islands there is a weir 206 ft. wide. The sills of these three passes are 17.9, 16.25 and 12.13 ft., respectively, below the level of the upper pool.

The gates and curtains are supported by Poirée trestles 19.5, 17.9 and 13.44 ft. high, respectively. They weigh 4 000, 3 000 and 1 760

lbs., respectively. The trestles are constructed of channel iron, and with two uprights front and back. They are joined by cross-bars forming caissons. The trestles are braced by a St. Andrew's cross. A Megy's endless chain is used to raise and lower the trestles, and is operated by a windlass on the shore. In the right arm of the river, *i. e.*, in the elevated pass, the Cameré curtains are used for closing the dam. The middle channel or weir is closed with Boulé gates, and the left arm or navigable pass is closed with gates and curtains alternately. The last method of arrangement has been proven best, for the reason that the curtains when rolled up do not always preserve a cylindrical form. This fact is likely to cause adjacent curtains to jam.

Maneuvers.—The general plan of operating Boulé gates and Cameré curtains is fully set out under those titles. To keep the pool at its normal level during the dry season it has been found sufficient in practice, to remove some of the top shutters if there is too much water, and to place small planks 1 ft. in width above the top of the gates and curtains in all the bays when it is desired to diminish the overflow. These planks are placed and removed by hand. M. Boulé considers them an essential part of his dam, and attaches considerable importance to their use in regulating the pool. In any case the Cameré curtains are unwieldy for the regulation of the pool, and especially if the lift is great. The effort required to raise a curtain from the bottom is evidently much greater than to remove a gate from the top. The curtains are likely to wear out if used for the regulation of the pool. Again, the currents flowing through at the bottom of the curtains are very swift, causing whirlpools and scour. The water in falling over the top of the gates produces no evil effects.

In time of flood the top rows of gates are first removed, and then the curtains are rolled up from the bottom. The head at this time is much reduced, and the rolling up is more easy than during low water. When the curtains are removed, the discharge through the openings is very great. If the flood continues, the gates are all removed and the trestles in the navigable pass are lowered. Thus the whole pass is opened to navigation with a depth of 10½ ft. on the sill.

The time required to either raise or lower the trestles of the pass (fifty-seven in number) is three hours. This maneuver may be performed at any depth of water, provided it does not reach the footbridge. As it requires a considerable delay in navigation to pass

boats through the lock, the trestles are always bedded as soon as there is sufficient water on the sill for the purpose of navigation. If the water falls, the trestles are immediately replaced in order to preserve a proper stage of water.

The time required to lower the trestles in the Suresnes dam is increased by reason of the fact that the curtains have to be removed by means of a special trolley carrying a small windlass for the purpose. The curtains have to be carried to a platform and hung upon a special frame in the same position as the dam. The operation is very laborious, as each curtain and frame weighs 1 600 lbs. When they are rolled up, débris of various kinds catches between the sticks, and they must be unrolled and cleaned. The method of removing gates is to pile them on a truck rolling on the bridge, when they are taken to the bank and tipped upon the ground. In the other passes, which are but little used for navigation, the trestles are not lowered until almost submerged.

A new lock 525 ft. long and 56 ft. wide has been placed between the left bank and the old lock. The latter has been rebuilt, and below it a lift wall has been placed. This is continued by a new lock 165 ft. long and 9.84 ft. deep.

Remarks.—This dam furnishes the only foreign example of an attempt to raise more than one trestle at once or to raise trestles by a stationary crab, and in this regard it is a great improvement over all other dams using trestles, except the needle dam in America. A French publication* thus describes the device, known as Megy's patent windlass:

"All the frames of the Seine pass are united by a continuous chain by means of link catches placed on their upper cross-braces. The length of the chain between two successive frames is greater than the distance between the axes of rotation, so that six frames are lowered or raised like the sticks of a fan; the chain is hauled in by a windlass placed on the abutment of the pass.

"By this system, having put the first frame in place, it is only necessary to haul in a short length of chain to bring the second into its upright position, and the operations of opening and closing the passes are almost reduced to the taking up or putting down of the rails and planks of the service-bridge.

"At Suresnes the opening of the navigable pass, 237.47 ft. (72.38 ms.) in length, is accomplished in three hours, and the closing in five hours with seven men."

*Notices sur les Modèles, Dessins, etc., Paris Exposition Universelle, 1889, p. 93.

By this method it is necessary for the crab to stop as each trestle comes to place and the chain-catch is removed from the trestle. The American device raises the trestles and places the foot-bridge or walk-way with only three men in less than 1¼ minutes per trestle, and the crab need never stop throughout the operation.

Bridge Dams.

The bridge dam invented by M. Tavernier and employed at Poses, Mericourt, Meulan and Port Mort, in France, and on the St. Mary's Falls Canal in this country, for dams of high lift, while more expensive than those heretofore described, yet may be advantageously used in many situations, particularly at points where a railway or highway is to cross a stream. While the application of dams supported by bridges is of late date, yet Mr. Frimot proposed such an arrangement in 1829, and a bridge dam was constructed on the Upper Yonne as far back as 1836 (Fig. 5). These designs, however, did not provide for navigation under the arches, except when the dam was open.

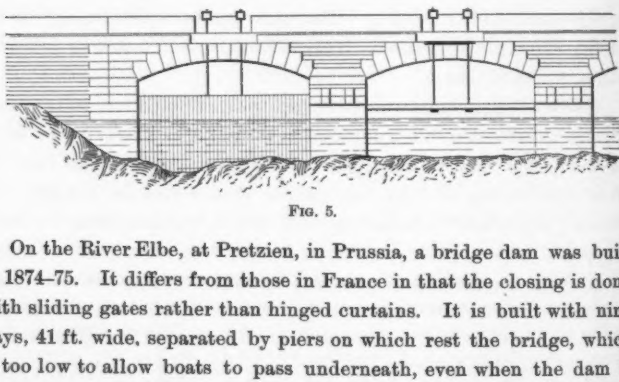


Fig. 5.

On the River Elbe, at Pretzien, in Prussia, a bridge dam was built in 1874–75. It differs from those in France in that the closing is done with sliding gates rather than hinged curtains. It is built with nine bays, 41 ft. wide, separated by piers on which rest the bridge, which is too low to allow boats to pass underneath, even when the dam is open. The floor of the dam is above low-water level. The pool rises 10 ft. above the sill.

The following description of the dam at Poses, which will give a general idea of the system, is compiled from that given in a government report.*

Dam at Poses, France.—The Poses dam, 771.5 ft. between the abutments, is divided into seven passes; five deep and two shallow ones.

* Un. Exp., Paris, 1889, p. 588.

The combination of the heights of the sills of the different passes was made so as to obtain a sufficient superficial flow by uniting as well as possible the transverse profile of the river at the right with the chosen location. The dam is thus divided into three distinct parts; two corresponding to the two arms surrounding Pointe Island, and the other to the cross-section of the island itself. The sills are placed at 11.32 ft. above tide-water in the first case, and 17.87 ft. in the second.

Depth of Foundation.—The exceptional height of the dam required the foundation to be laid upon a solid and impermeable stratum, thus avoiding all filtration which would compromise the stability of the structure and absorb a portion of the flow during low water, when most needed for navigation. It was found best, as in the case of the locks, to descend to a bank of solid chalk which is met at about 5 ms. below the sea level for the whole width of the river-bed.

Piers and Abutments.—The piers are 13.12 ft. thick. On the down-stream side, the starlings project a considerable amount beyond the roadway, and support masses of masonry which rise to the top of the bridge. These masses serve to resist the horizontal thrust which is transmitted to the bridge by the suspended frames. The piers and abutments are pierced by full-centered arches 4.26 ft. wide and 7.54 ft. high, so as to allow the service-bridge to be freely carried through them. In these passages niches are made in which to store the curtains and windlasses.

Flooring.—The surface of the flooring is plain, at the level 10.16 ft. above the sea for the deep passes, and 17.06 ft. for the shallow ones. This surface is limited on the up-stream side by a sill curved up just above the level of the hurters, so as to protect them against the keel of any boat or the shock of any bodies against them. The hurters are 3.80 ft. apart, built into the flooring and projecting 1.15 and 0.82 ft. above it in the deep and shallow passes, respectively. They are protected by flanged iron plates fastened to them. A bolt, passing horizontally through each stone, is secured by a nut at the back. This bolt is also secured to the anchorage bar of the flooring so as to transmit to the piers the longitudinal pressure of the uprights. The hurters rest against the plate band of hewn stone. To increase the solidity of the whole, the two limiting walls of the flooring are united by tie rods sunk in the masonry and passing between the hurters. Finally, a row of cast-iron boxes and anchor rings have been sunk in the ma-

sonry flooring in front of and behind the hurters, so as to permit a coffer dam to be rapidly set up in case of repairs.

Upper Bridges.—The system adopted at Poses requires the establishment of two upper bridges, according to the idea of the late M. Tavernier. First, the down-stream bridge to hold the suspended frames, and second, the up-stream bridge to hold the windlasses while the frames are being raised, and also sustain a part of the weight of the raised frames themselves. The first may be called the suspending, and the second the hoisting, bridge.

The roadways of the two are for two different purposes and at different levels. The down-stream longitudinal girder of the hoisting bridge is omitted, and its supporting cross-girders are attached directly to the longitudinal up-stream girder of the suspending bridge, thus affording easy communication between the bridges, and adding to the horizontal strength of both. The up-stream roadway has an opening 4.99 by 8.20 ft.; large enough to admit of passing the curtain through it endwise. In the non-navigable passes the facility of communication is insured by putting a third roadway above the beams of the down-stream roadway.

The lattice girders supporting the roadway have their uprights 7.61 ft. apart, corresponding to the widths of the moving parts. The cross-girders take the strain of the hanging frames by means of the brackets arranged under them. These girders, 3.80 ft. apart, are braced by U-irons placed on each side of the rods suspending the frames. The brackets are trapezoidal in form and 2 ft. high. Upon each of their faces two angle-irons are riveted, projecting on each side and forming a guide. The heads at the end of the suspending bars rest upon these guides at a height 1.64 ft. under the cross-girders, so that the uprights can be raised to the flanges of these girders, that is, so that the uprights may clear the hurters.

The width of the up-stream roadway depends on its height above the water. There must be space enough, from the end girder to the point where the chain comes through, to work the windlass; also to give the chain a proper inclination, to avoid too much tension on it. At Poses the chain is attached to the frame at 2.95 ft. below the water level, and the chain is inclined 33° at the beginning. The distance between the principal girders of the up-stream roadway is 24.76 ft. for the navigable passes, and 17.22 ft. for the non-navigable.

The up-stream roadway is placed halfway up the principal girder, so as to allow sufficient space below the cross-girders to store the rolled curtain when the frames are raised. The cross-girders are 7.61 ft. united by stringers. The beams of the upper bridges rest on their piers and abutments by a hinged joint, so that the resultant of pressure always passes through the center of contact, whatever may be the deflection of the beams themselves. Expansion trucks are placed vertically between the down-stream girder and the massive starling.

The uprights, which support the curtains, are wrought-iron beams with angle-irons, having their mean fibers inclined so that the vertical passing through the center of gravity of the frame with its curtain and foot-bridge is on the up-stream side of its upper joint. The uprights have a U-shaped section, which is constant in width, 8.20 ft. above the upper bay for the same pass; this width is 1.64, 1.96 and 2.30 ft. for the three passes, respectively. Above this level the width tapers to 0.82 ft. at the top.

The joint of the uprights with the suspending shaft is made by a cast-steel eye wedged to the shaft, terminated by a cheek which is riveted to the web of the upright. Lengthwise the uprights are arranged in groups of two, and the axes of these groups are 3.80 ft. apart. The object of this division was to reduce the width of the moving pieces to 3.80 ft., in case the length of the curtains, 7.61 ft., should be found too great; but as this length has been found convenient, the arrangement of the uprights in subsequent dams of this type has been simplified. At Port Mort, for example, the uprights have a double T-section.

Frames.—Each frame is formed of four uprights, united by ties 6.56 ft. apart, and having a width 0.49 ft. less than that of the upright, so as to afford a passage to the hoisting chains and a lodgment for those of the frames. One of these ties is on the level of the service-bridge, and upon it is a cast-iron box which holds the slack of the curtain chains. The uprights of the same frame are also tied by three shafts, viz., first, the upper suspending shaft; second, the shaft 6.56 ft. above the service-bridge, used for attaching the hoisting tackle of the service-bridge; third, that to which the hoisting chains of the frames are attached.

The Hoisting Chains.—There are two hoisting chains for each frame; each chain divided into two branches, so that the end of one

branch is attached to each upright, thus dividing the strain of lifting the frame into four equal portions. On the down-stream side of the uprights, a strong wrought-iron hook with angle-irons is attached, for the purpose of raising the frame in case of accident to the chains or to their attachments. This can be done by lowering, along the upright, a chain, the bight of which will be held securely by the hook. Ringbolts are attached to the up-stream side of the uprights, so that the frames may be slung below the upper bridge when any repairs are required.

Method of Suspending the Frames.—The method adopted for suspending the frames has been somewhat simplified in the more recent dams. The suspending rods are terminated by cross-heads fitted to the rods by gibs and cotters; these wrought-iron rods have a cross-shaped section, and pass between the braces of the down-stream roadway, above which they are united, two by two, by a cross-piece having the section of a double T, whose extremities can slide vertically between the uprights of two cast-iron chairs bolted to the roadway: In their normal position, these extremities rest on chairs by means of regulating iron wedges. Similar wedges placed between the upper face of the cross-piece and the upper bearings of the chairs prevent the frames from lifting.

Foot-Bridge.—The foot-bridge, made up of framed sections, is constructed of U-iron, to which the iron flooring is riveted. Upon this flooring the rails for carrying the windlass are laid. The up-stream side of the section is hinged to the down-stream side of the uprights. The transverse bars of the section are prolonged, and strike against corbels riveted on the webs of the uprights, so as to keep the sections of the foot-bridge horizontal when it is lowered.

Method of Attaching the Curtains.—The suspending chains are hooked to rings attached to the two outside uprights of each frame 4.10 ft. above the foot-bridge. The two pulleys for rolling the curtains are placed between the intermediate uprights. The lower pulley, holding the down-stream chains, is slightly smaller than the other. This inequality insures a distance between the chains equal to the thickness of the first curtain bar. Besides rolling the curtain, each side of the endless chain can be fixed upon its guide pulley by a stop carrying a finger, which enters the link of a chain when the lever is lowered. Finally, the uprights have on their up-stream faces iron claws, which serve as stops to the rolled curtains.

Details of the Curtains; Dimensions.—Each curtain corresponds to an opening 7.61 ft. wide and 17.55 ft. high in the deep passes. The bars are of yellow pine, each 0.25 ft. high, with a slight play between them to allow for swelling. Their length is 7.47 ft.; giving a play of 0.13 ft. between two neighboring curtains. This interval is sufficient, and can be closed by a joint cover if the dam requires to be made tight. The thickness of the upper bar is 0.13 ft., and it increases progressively downward to 2.95 ft. The upper bar, exposed to shocks from floating bodies, is strengthened by an angle-iron. The hollow cast-iron rolling shoes are heavy enough to cause the curtain to sink easily into the water when unrolled. The rows of hinges form a kind of chain, resisting all efforts exerted on the chain in the act of rolling. These hinges are of bronze, so as not to rust. They have strong flanges, and their axles are of drawn phosphor-bronze. All the handling machinery can be carried on cars rolling on the service-bridge tracks.

To Raise the Frames.—With the suspension above described and in use at Port Mort, the operation is as follows: Lifting jacks are placed under the cross-pieces uniting the two suspending rods of a frame above the down-stream roadway. Each jack rests upon a platform arranged for this purpose in the horizontal bracing of the roadway. After placing the jack and removing the wedges which prevent the lifting, the jack is screwed up, care being taken to wedge the ends of the cross-piece as it moves up. This wedging serves to sustain the lifted frames. The chains from the windlass on the upper bridge are then hooked on, and the frames are rotated to a horizontal position and made fast to the under side of the upper bridge.

Cost per Running Foot:

Masonry foundations......................	$813.72
Iron-work:	
Upper bridges............................	114.09
Frames..................................	53.54
Curtains, etc............................	25.68
Total..........................	$1 007.03

The cost of wicket dams in France ranges from $183 to $600 per foot run; that of needle dams from $153 to $244.

Thenard Shutter Dam.

In the description of shutter dams the term "shutter" applies to those barriers in which the axis of rotation is at one edge, and the term "wicket" to those in which the axis is at or near the middle. The earliest types of shutter dams were constructed on the overfalls in the River Orb during the 18th century.

M. Thenard on taking charge of the River Isle, in 1828, found several fixed masonry dams. These did not give a navigable depth to the stream at low water, but caused overflows of adjoining lands at high water. They averaged 6.56 ft. above low water. His project was to lower them to 3.93 ft. and to secure a depth sufficient for navigation by placing a movable dam on top of the fixed one. His first experiment was tried at the dam of St. Suerin in 1831. He took the Orb dam as his model and improved it. The Orb consisted of wooden shutters hinged to the floor of the dam and capable of being raised or lowered at will. He first invented a tripping bar which tripped the props successively, and allowed the shutters to fall one after the other. This rendered the lowering of the wickets a very easy matter, but the raising of them was very difficult, as they must be raised against the current. To facilitate this, Inspector-General Mesnager advised M. Thenard to build counter-shutters falling up stream in order that they might be raised by the force of the current and form a temporary dam while the permanent shutters were being raised. This arrangement allowed the lock-keeper to walk dry-shod on the floor and raise the shutters and to place the props without fear of being washed away. This idea was in use at the dam of the Caillade, of Coly-Lamelette, and at Fontpeyre from 1839 to 1841. These are perhaps the only distinctive Thenard dams. The following is a description of them:

These dams were 155.8 ft. long, or, including the passes, about 230 ft. On the crest of the masonry dam is a wooden sill, firmly bolted to the stone work. Panels are 6.56 ft. long and 3.28 ft. high. The down-stream shutters are supplied with wrought-iron props, and the up-stream ones with forked chains, being anchored to the floor at one end. The foot of the prop rests against an iron hurter or sill fixed to the floor. The tripping rod is made of iron, and extends lengthwise of the dam. It is furnished with teeth, which are grasped by a cog-wheel operated by a jack on shore. It has as many teeth as there are

shutters. The props are tripped in succession. Every time the bar moves $1\frac{1}{8}$ ins. a shutter falls. When they are all down, the tripping rod is drawn back to its first position. After the tripping rod has pushed the prop sidewise from the supporting hurter, the force of the water above causes the shutter to fall down stream.

The up-stream shutters, or counter-shutters, when lowered, are held in place by spring latches fitting into an ear on the floor. When it is desired to raise the up-stream shutters this spring latch is released by a tripping rod, and the shutters rise by force of the current. When they are upright, they are held in place by the chains. The lock-keeper then goes down to the floor and raises the down-stream shutters by hand. He then equalizes the water level above and below the counter-shutters by opening small valves in them, when he pushes them down with a pole until the latch is caught. The whole maneuver has been performed in $16\frac{1}{2}$ minutes.

In 1843 he erected the St. Antoine dam. The height of each panel was 5.57 ft., and the width 3.89 ft., being very much higher than his former attempts. He also constructed a sheet-iron foot-bridge on the top of the counter-shutters, upon which the dam-tender could stand in raising the lower shutters.

The Thenard dams were thought to be impracticable if over 4 ft. high, but they are now in use in India on the Mahanuddee and the Cossye rivers and on the Sone Canal, where they sustain pressures in excess of 10 ft. They seem better suited to the Indian rivers than any other system. They have the advantages of being very simple, and hence of never needing repairs; and they furnish no projections, so that the largest ice fields can pass over without injuring the dam. The practicable application of this dam is difficult on high lifts, because of the weight of the shutters and the force of the current. It is difficult to keep the floor below the shutters dry enough to allow the attendant to operate without being in the water. A boat has been substituted, in which the attendants sit and operate the shutters by windlasses. The shocks on the chains holding the counter-shutters often break them and loosen their fastenings.

In streams carrying large quantities of drift, or where ice is liable to form before the season for lowering the dam has arrived, this dam, with some modifications, can be used to better advantage than the Chanoine wicket, which succeeded in France.

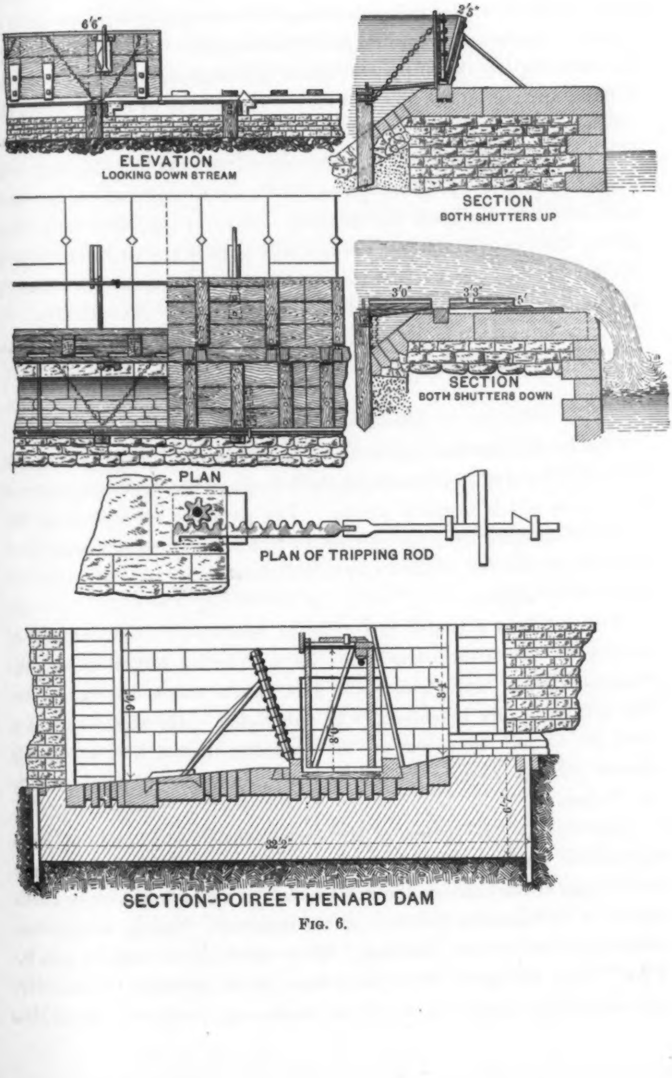
Poirée-Thenard Dam.

To overcome the objection of a double set of shutters in the Thenard dams, M. Chanoine substituted for the counter-shutter a row of trestles, upon the up-stream side of which were placed needles—in short, a Poirée dam. In the operation of passes which must be rapidly maneuvered, the Poirée dam is first put in place, forming a protection behind which the attendants raise the Thenard shutters. They operate from the foot-bridge by the use of a windlass. The dam constructed on this plan at Courbeton across the Seine was built in 1850, and has worked well since. The needle dam is 124 ft. 8 ins. long, and abuts against the tail wall of the lock. The pass is 39.68 ft. long. The pass only is constructed on the combined system, being separated from the main dam by a pier 3 ft. 3 ins. thick. When the pass is closed the shutters are raised and the trestles may be left standing or not as desired. They are usually kept up in low water, although the needles are removed (Fig. 6).

At this dam a turbine wheel is fixed in the shore abutment for the purpose of operating the tripping bar. It works automatically. When there are enough shutters down to reduce the pool to its former level, the water-wheel stops, and the pass is opened no further. In high water the wheel continues to work until all the shutters are down. After the water-wheel has tripped all the shutters, it is thrown out of gear by a pinion on the rod. After the flood subsides, the needles are placed in position and the shutters raised as described.

Remarks.—This combination is a great advance over the Thenard system alone, and it is surprising that its use has not become more general. For rivers carrying drift, it probably has no superior, if properly constructed. With the improved methods of raising the trestles and the simultaneous placing of the needles, which can be very light and wide, because the head to be sustained will be small, a dam of this type could be very rapidly and easily put up. The lowering could take place either by the Pasqueau method or by use of the tripping bar. The trestles could be lowered previous to all danger from drift or ice.

To operate such a dam it would first be necessary to raise all the trestles. As the head to be sustained would be only that which accumulated while the shutters were being raised, it would be small, and therefore the trestles could be light and of wide span and without es-



SECTION-POIREE THENARD DAM

FIG. 6.

cape bars. They would be raised at the rate of at least one trestle per minute, or say 100 ft. of dam in ten minutes. After the trestles were all up, the needles could be either carried, taken on a truck, or transported in a boat and placed ready for dropping into position on suitable brackets or supports along the trestles. When all were ready, the releasing of the supports would simultaneously let fall all the needles and cut off the flow of water. The raising of the shutters, the chains of which come up with the trestles, can then be effected in quiet water by the methods now in vogue on wicket dams. On very long dams it would be advisable to raise them from each end at the same time, so as to facilitate the erection. After all shutters have been raised, the removal of a few needles will permit the pressure to come against the dam proper, and the needles in place will at once float up and can be loaded into a boat or carried ashore. The trestles can either be left standing for convenience in crossing, etc., or they can at once be lowered out of harm's way.

Girard Shutter Dam.

The Girard shutter dam consists in the application to a Thenard shutter of hydraulic pressure applied through the instrumentality of a jack into which works a piston. The pressure for operating the piston is obtained from pumps worked by a turbine water-wheel which is moved by the fall of the water. The shutters are closed against the force of the stream.

This dam was invented in 1869 by M. Girard, a French engineer of eminence. M. Girard was killed by a Prussian bullet during the Franco-Prussian war, before the dam, upon which he was to try the utility of his invention, was completed. He was awarded a contract to put in seven of his shutters on the weir of the Ile Brulée dam at Auxerre on the Yonna. The work was completed by M. Callon.

Description.—The system of M. Girard consists of a series of large shutters or wickets moving around a horizontal axis placed at the lower edge of the shutter, the axis turning in a cast-iron hollow quoin which is embedded in the crest of the masonry. The Ile Brulée dam contains seven of these shutters. They are 11.55 ft. wide by 6.46 ft. high. They are made of fir joists 4 ins. thick, fastened to the lower axis and to the upper timber of the shutter and joined at the middle

to the cast-iron cross-head of the connecting rod. Each shutter is composed of three pieces of I-shaped wrought iron, fastened to the axle at the bottom. The joists are fastened to the up-stream side of these I-irons, and on the lower side is a plate of sheet iron. The space between consecutive shutters is $1\frac{3}{4}$ ins.

Attached to each shutter is a hydraulic jack. It is fastened to the down-stream side of the floor, inclined 10°, and firmly anchored in the masonry. The jacks are made of cast iron. Their exterior diameter is 16 ins. and their walls are $1\frac{1}{2}$ ins. thick. Into each jack works a piston. The piston is of cast iron, covered with a jacket of red copper. It is 12 ins. in diameter, and slides through a stuffing-box of hammered copper, which forms a joint that becomes tighter as the pressure increases. The piston carries a cast-iron cross-head which is guided in its course by three connecting rods, joined to the cross-head and fastened at the middle of the shutter. This latter cross-head moves in a hollow quoin also. The connecting rods transmit the power of the jack to the shutter.

Each jack is supplied with a copper pipe, 1 in. in interior diameter, entering the jack at its lower end. These copper pipes connect with the generator and accumulator of pressure, and carry the water pressure to the jacks.

On the abutment is built an engine-house containing a turbine wheel, a double acting water pump, an air pump, and an air chamber, or accumulator of compressed air. The turbine wheel has a vertical axis, and is 4 ft. in diameter. A crank at the top of the axis works the water pump, which is provided with a plunger, and also the air pump, both pumps being operated by the same piston rod. The water pumps draw water directly from the river if it is clear; otherwise from a reservoir in the abutment. The accumulator is a cast-iron cylinder whose interior diameter is 26 ins. and whose height is $11\frac{1}{2}$ ft. The cylinder walls are 2 ins. thick.

Communication is established between the pump, the accumulator and the jacks by means of three-way cocks, which allow water to be introduced into the cylinder, and the removal of the same by means of a discharge pipe. They also establish direct communication between the cylinder and the pump, if it is not desired to use the accumulator. They send the water from the pump to the accumulator, or they shut off everything.

Maneuvers.—The shutters are maneuvered by turning the cocks. By putting each jack into connection with the pump, or with the accumulator, the piston is made to run out of the jack, and, consequently, the shutter is forced up. To lower the shutter, the cock is opened into the discharge pipe, the water runs out and the pressure on the shutter causes it to fall. When down, it lies flat on the masonry and forms no obstacle to navigation. The accumulator is intended as a governor for the pumps. By it also the shutters may be raised when the upper pool is too low to set the turbine wheel in motion.

Supposing the pass and the weir to be entirely open, and the accumulator empty, the Girard dams can be maneuvered only by creating a fall sufficient to set the turbine and the pump in motion. The Ile Brulee dam is supplied with Chanoine wickets in the pass. These are closed by a maneuvering boat. This raises the level of the water sufficiently to start the turbine, and the jacks may be worked directly from the pumps.

The accumulator should be used, as a general thing. When it is empty, the air pump is set in motion until it compresses the air to 10 atmospheres; then the water-pumps force water into the accumulator until the air pressure is from 20 to 25 atmospheres. If the fall is light, the accumulator has power to raise the whole dam. The time taken for this maneuver is less than half a minute. If the fall is over 3 ft., the pump must be kept at work, to assist the accumulator. The time required in such a case is about 5 to 6 minutes, and the total raising of the dam requires not more than 10 to 15 minutes.

The shutters may be lowered with equal facility by turning the cocks so as to open into the discharge pipe. It requires about 2 minutes to lower a shutter. The jacks may be raised or lowered at will, and independently of each other, so that any height of the upper pool may be maintained. The shutters may be stopped at any point by turning the cock. This is useful in moderating the scour and in preparing for a moderate rise.

Maneuvering is rendered easier by the construction of *Papillon* valves. When the shutter is down, these valves open by the pressure of the water, so that only their thin edge sustains a pressure. The resistance in raising is thus diminished. When raised, the valves close

themselves. Each shutter is provided with three valves 2 ft. 11 ins. wide by 2 ft. 8 ins. high. The valves also assist in regulating the height of the pool.

Construction.—The weight of each shutter is 2 552 lbs. The weight of each piston is 3 908 lbs. The hydraulic jacks sustain a pressure of 1414 lbs. to the square inch under a pressure of 25 atmospheres, and the accumulator 2 404 lbs. The copper pipes, 1 515 lbs. The strain on the piston and connecting rod is about 2 830 lbs. per square inch. The strain on the shutters, 256 lbs. If a greater pressure than 25 atmospheres is generated, the air will escape through the joints and cocks, and to prevent this they should be lined with lead.

The cost of constructing this dam of seven shutters at Ile Brulee was $8 600, with $1 150 for contingencies and extras, thus making the total cost, not including masonry, $119 per running foot. The masonry, including coffer dams and excavations, cost $60 per foot, making a total of $179 per running foot.

Conclusions.—The Girard dam is very easily and rapidly raised and lowered without shock. The experiment as tried at Ile Brulee is said to have been perfectly successful.

The leakage is very materially reduced on account of the large wickets and the smallness of the openings between them.

It is applicable to lifts of any height and to great lengths of dam.

Objections have been urged against the use of this dam as follows:

It is a complicated piece of machinery and likely to get out of order. The greatest of care should be necessary to secure continued successful operation.

It was feared that the jack would become filled with sand. This, it is thought, is not well founded, although, if this system were used in the navigable pass, sanding up would be more likely to occur.

Freezing weather would be a very great detriment. To avoid this the jacks have to be placed below low-water line. This renders it difficult to make repairs. The pumps, the accumulator, and the cocks are in a building which could be heated in winter time. Carelessness in cold weather would freeze this dam up and render it useless. It was thought that by the use of alcohol and water mixed, the freezing temperature would be sufficiently lowered to prevent danger. This would be found too expensive, as 27 galls. of water daily are required to operate the jacks.

Janicki Dam.

This dam is the invention of S. Janicki, a Russian Engineer, and director of the Moskva Navigation Company. The author is not certain whether to place it among those which have been employed in the improvement of rivers, or whether it is still among those characterized by M. Malézieux as "projects, studies, experiments, inchoate ideas, more or less venturesome."

M. Janicki in describing his invention says:

"Being under the necessity of planning a dam for a very wide river (1 300 ft.), whose floods are very rare and slow, I thought of applying the system of Poirée trestles and Boulé gates similar to those of the Moskva. But the use of trestles on wide rivers has the disadvantage, that all must be dropped in the same direction, requiring much time. In the solution offered, the skeleton and the screen are separated, the same as in the Poirée-Boulé combination, but the trestles fold up and lie down horizontally, parallel to the thread of the stream, independent of each other."

This trestle is, in fact, the frame of a Thenard shutter with foot-bridge added, over which may be placed planks, gates, needles, and shutters for stopping the water. In his own words the dam is described as follows:

"The up-stream standards of a trestle are composed of two double T-irons, suitably connected and braced so as to form a rigid frame, upon the up-stream side of which the movable gates are slid into place from above, when the dam is to be closed up after raising. Each frame has an axis of rotation at its lower end, which passes through journal boxes fastened to the floor. A second axis, near mid-height of the frame, serves as a hinge for the heads of the props, which hold the frames after they are raised. The feet of these props rest against double-stepped hurters of the Pasqueau system.

"The width of the frame, forming the up-stream face of each trestle, depends on the width to be given to the gates. As a rule, this width will be the same as the distance between the trestles of the ordinary trestle dam. The distance between the adjacent standards of two consecutive trestles should be the same as the distance between the standards of the same trestle, in order that the closing gates may rest discriminately, either against the standards of the same trestle, or against the standards of two consecutive trestles.

"From what precedes it will be seen that each chief standard with its props forms a kind of trestle that can fold up and lie down horizontally parallel to the thread of the stream. In order to compel these folding trestles to always keep in the same vertical plane, parallel to the current, while they are being raised or lowered, we connect

them two by two, as has already been said, both by means of the axes, which serve as hinges, and by the braces that hold together the two principal up-stream standards.

"It is also practicable to add to the rigidity of the system by partly bracing together the two props of the same trestle. Below the front rank of principal frames there is placed a second rank of very light frames similar to the first, and connected with the latter on top by cross-pieces parallel to the thread of the stream. These two frames, thus connected by cross-pieces, having axes of rotation at the points of intersection, form, in the vertical plane parallel to the current, two movable parallelograms which can fall down stream and lie horizontally on the floor.

"When the system which has been described is upright, supported by the props, each trestle forms a skeleton, which can serve both as a service-bridge for placing and maneuvering the gates, and also as a support against the pressure of these gates.

"The operation of raising a dam composed of such trestles is performed as follows: On a small railroad on the abutment there is a rolling crane, suitably weighted, having an adjustable boom. This crane, which is worked by hand, begins by raising the first trestle, which is lying on the floor, at the distance from the bank equal to its width; as soon as the feet of the props are heard to fall into their seats, the crane ceases to raise. Two balks are placed from the abutment to the cross-pieces of this first trestle. On these is laid the flooring of the service-bridge, and then the crane is run forward on this first piece of dam. From this point the second trestle is raised and the second piece of dam is erected, and so on to the end. When once all of the trestles have been raised, the horizontal gates are brought up on trucks and are put in place by hand, as is done on a trestle dam.

"To perform the reverse operation, that is, to lower the dam, we begin by lifting and removing all the gates by hand, with the aid of boat hooks, and with the same crane we raise slightly the trestle, which we wish to lower, until the prop falls off of the sliding step; the crane then lowers the trestle and its accessories to the floor. During this operation the crane travels backward, until it reaches the abutment, whence it began the operation of raising.

"From this concise description, which shows the idea which guided us in proposing the kind of dam of which we are speaking, the advantages of using it can be deduced. They are as follows:

"1. By this system, a dam of any length whatever can be built without intermediate piers.

"2. A dam of this kind gives a surface overflow along its whole length, and it is exactly as water-tight as a trestle with Boulé gates.

"3. The operations of raising and lowering a dam of this kind can be begun simultaneously from the two abutments by means of two dif-

ferent cranes, and it is even possible, if greater speed is desired, to raise the trestles by means of boats equipped with light shears.

"4. Should the dam be sanded up at one or at several places, the raising of the trestles is not hindered, since it is practicable to raise at will any of the parts of the dam which are not covered; and by increasing the current over the sanded parts, they are rapidly cleaned off.

"5. Since in our style of dam the skeleton serves also as a service-bridge, this style must necessarily be cheaper than those in which it is necessary to place above the true dam a special service-bridge. For the same reason the operations of raising and lowering such dams are more rapid.

"6. The kind of dam thus described can be used for the greatest lifts without inconvenience."

Bear-Trap Dams.

It is not proposed in this paper to take up at length any of those forms of dams maneuvered by the force of the water, and a brief description of their principal points is all that will be attempted. The paper of Mr. A. O. Powell, published in Vol. XVI of the Journal of the Associated Engineering Societies is accessible to all, and amply discusses these forms of dams. Nowhere have they been applied to navigable passes of great or even ordinary width; and in their present state of development they can scarcely be classed as movable dams, in the true sense of the word, but rather as gates for sluices, locks, etc. That the time is fast approaching when they will be largely used for purposes of navigation is not doubted by many able engineers who have been for years trying to solve some of the difficult problems connected with their successful operation.

Original Form.—The American bear-trap dam, first used in 1818 in the Lehigh River, by Josiah White and Erskine Hazard, is the earliest of the modern movable dams, and presents many admirable features. It went out of use, practically on account of its cost and difficulty of operation, as originally built; but interest in it is now being revived, with fair prospects of its introduction on navigable streams.

It consists of two gates, an up-stream and a down-stream one, revolving around horizontal axes fixed to the floor; the up-stream one overlapping the down-stream one, when down, and resting on its point when raised. The gates close tightly against each other and against the side walls. Two culverts are built in the side walls, end-

ing in the upper and lower pools. A passage connects the culverts with the space under the gates, and the culverts are provided with valves for making connection with the pools. The pressure under the gates is increased when water from the upper pool is introduced, and the gates rise. Strips on the side walls, or stay-chains, prevent the gates from rising too high.

The principal defects in the original type are:

(1) Sliding friction between the leaves.

(2) Width of base too great for height attained.

(3) The overlap of upper upon lower leaf.

(4) Inability to rise or fall uniformly.

(5) Necessity for initial head in raising.

(6) Difficulty of stopping without shock when rising.

(7) Difficulty of operation in wide passes, and division into several sections.

(8) Leakage at time of raising.

(9) Liability of binding on débris along side walls and driftwood lodged in the exterior angle between the leaves.

(10) Cost.

Modifications; Carro.—The first objection was overcome by M. Carro, a French engineer, by hinging the leaves together at the apex; but in so doing he gained but little, as his up-stream leaf must slide at the bottom, back against the head of water. This dam consists of two gates, or rather one connected by hinges, and resting on wooden axles, whose ends are journals provided with rollers, which roll on rails parallel with the thread of the stream. Links fastened to the lower gates are also fastened to fixed points distributed along a right line parallel to the crest of the dam. There is a passage under the gates 2 ft. deep. When the gates are up, they have the appearance of a bear-trap dam. They are lowered by the ends rolling in opposite directions until the gates lie flat. The conduit running beneath the gates is put in communication with the upper pool by halves for raising the gates, and, by shutting off this connection and opening the valves into the lower pool, the dam is lowered.

The pressure of the water is exerted under the lower gate, and it communicates the force by way of the hinges to the upper gate. The latter only plays a passive part. When the gates are clear down, the upper gate prevents the lower one from rising spontaneously.

Parker.—The defects of sliding friction and wide base were remedied by Thomas Parker, who not only retained the old hinges of the bear-trap and the new one of Carro, but added a fourth by dividing the upper leaf into two parts, which, when down, folds inward upon itself, similar to the idea of the French engineer, Girard, who, however, placed his joint in the lower leaf. Mr. Parker's invention pretty well overcomes many of the objections above given. There is no sliding friction, the width of base is greatly reduced, the overlap is done away with, the construction necessitates uniformity in raising, it cannot come to a sudden stop, it need not leak, and its cost is not necessarily excessive. The difficulty of drift catching in the folding leaf is overcome by the introduction of an idler or auxiliary leaf hinged to the apex and covering the joint, and sliding at the foot on the floor. The application to wide passes has not been assured, however, nor has the ability to rise, without increased head. Parker gates have been built only to a limited extent, and so far as known to the author, the one at the Muscle Shoals Canal (40 ft. in length and 8½ ft. high) is the longest one yet erected.

Lang.—Robert A. Lang conceived the idea of making the idler an essential part of the gate and substituting chains for the upper section of the up-stream leaf. Thus the idler slides on the lower section and reintroduces sliding friction, but the effect of this friction is partially overcome by the weight of that portion of the gate suspended in the air, just at the point when it would be most troublesome. The use of rollers on the edge of the idler will doubtless greatly reduce the friction. Quite a number of Lang gates have been built and are in successful operation as lumbermen's dams and for power companies, and the United States have recently completed one at Louisville (Fig. 7).* These dams range in length from 11 to 80 ft., and in height from 6 to 16 ft. The gates at Sandy Lake reservoir in Minnesota, built by the United States, are respectively 11 ft. long and 12 ft. high, and 40 ft. long and 13 ft. high. A letter to the author from Lieutenant-Colonel W. A. Jones, the officer in charge of the district, dated May 7th, 1897, says: "The gates at Sandy Lake dam have been subjected to practically all possible conditions of water above and below. There is no doubt of the success of this form of movable dam. There have been no failures of this form of gate thus far; they operate quickly; one man with a short, easy stroke at the wheel does it." A full descrip-

* Modified Parker, not Lang. See Captain Warren's discussion.

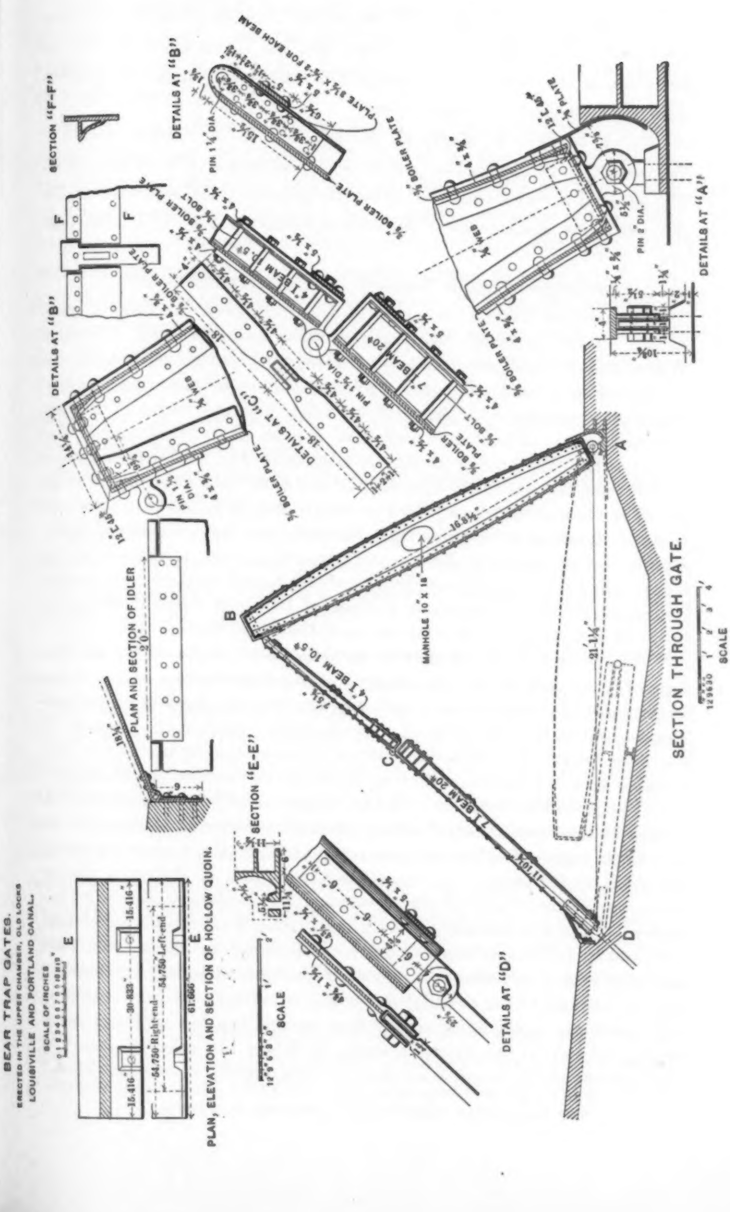

BEAR TRAP GATES.
ERECTED IN THE UPPER CHAMBER, OLD LOCKS
LOUISVILLE AND PORTLAND CANAL.
SCALE OF INCHES
PLAN, ELEVATION AND SECTION OF HOLLOW QUOIN.
SECTION "E-E"
DETAILS AT "D"
PLAN AND SECTION OF IDLER
DETAILS AT "B"
SECTION "F-F"
DETAILS AT "C"
DETAILS AT "A"
MANHOLE 10" X 16"
SECTION THROUGH GATE.
SCALE

Fig. 7.

tion of these gates may be found in the *Journal of the Association of Engineering Societies*, Vol. XVI, page 210, and also a more general description in the same volume, page 238, where a design for a 600-ft. dam is presented by Colonel Jones.

Marshall.—Wm. L. Marshall, M. Am. Soc. C. E., Major, Corps of Engineers, U. S. Army, has patented several forms of bear-trap gates. The general features of two of these designs are fully described in *The Journal of the Association of Engineering Societies*, Vol. XVI, 1896, page 218.

A later design of Major Marshall is thus described by him:*

"The object of the invention is to so improve the dam or gate, known as the original bear-trap, devised and invented by Josiah White, that it shall preserve the advantages of that gate due to its disconnected or separate leaves, while at the same time the possible height of crest above the foundation, relative to the width of the base or development of leaves of such dam or gate, shall be increased; also to so improve the known means of admitting and withdrawing water to and from the hydraulic chamber of the dam that twisting or warping of the leaves may be avoided or controlled, thus making long continuous dams possible; also to so restrain the motions of the down-stream leaf by water brakes, as to prevent anything like a ramming action when the gate is brought to its fully raised position; but instead to gradually stop the upward motion of the gate without the possibility of carrying away the fastening of the lower leaf.

"The invention is designed to secure smooth surfaces for the passage of drift, and all the advantages of separate leaves, and also the advantages of jointed leaves, without incurring the disadvantages common to hydraulic dams with the leaves hinged together at the crest of the dam, which construction involves, in most hinged-leaf dams, four parallel axes of rotation, which are difficult to practically construct.

"The invention consists in a dam or gate of two disconnected leaves hinged to the foundation; the down-stream leaf having attached to its up-stream edge a rotating shoe or toggle leaf, which travels on rollers along the under side of the up-stream leaf until it strikes a stop or quoin on the under side of the up-stream leaf at the top, by the resistance of which it is forced to rotate, and further push up the up-stream leaf; and in adjustable telescoping tie rods, some or all of which are provided with a cylinder and piston or plunger, attached to the down-stream leaf and to the foundation; which constitute hydraulic brakes, and which are brought into play first before the toe of the shoe or toggle leaf strikes the quoin or stop, to bring the gate gradually to rest without shock to gate, stops or quoins, fastening or toggle joint."

* Patent Office Application (by permission of inventor).

Du Bois.—John Du Bois applied an apron to the down-stream leaf of an old bear-trap in order to provide a more even slope in the intermediate positions of the dam. He also hinged the leaves at the apex before M. Carro.

Wood.—The dam proposed by Capt. J. A. Wood, of Pittsburg, is a modified bear-trap, very similar to that of M. Carro. It dispenses with the links of the latter, and does not utilize the water of the pool for raising the dam. The gates are, however, hinged together, and the down-stream gate is kept down on its iron track. His method of maneuvering was that of chains wound around an axle under the gates, to be operated by steam or water power. The upper gate turned on an axle fastened to the floor; the apron of the lower gate was allowed to move forward and back in grooves. By winding it on the windlass, the apron moved up stream, forcing the dam to rise. The contrary motion lowers the gate. The objection to this dam is that it does not utilize natural forces.

Problems.—The problems to be solved before a satisfactory bear-trap dam can be designed are:

(1) The distribution of the water under the dam in such manner as to raise or lower the gates without warping, twisting or injury.

(2) The securing of the power necessary to start the gates upward where no natural head exists.

(3) The application of the gates to passes of great width without the introduction of piers or other obstructing parts.

(*1*) *Uniform Movement.*—The first of these problems, the distribution of the water supply utilized in raising the leaves so that the gates will rise or fall uniformly without warping, may be solved in narrow chutes, as at Davis Island drift gap, by introducing the water from each end of the gates. In wider openings, the proposition has been made to fill through culverts with orifices discharging directly under the gates at intervals. Still another plan has been proposed to assure uniform raising, that of building the dam so tight that leakage will be impossible. In this way water can be admitted slowly and have time to distribute itself. This suggestion has much good sense in it.

Mr. Du Bois proposed and unsuccessfully tried racks and pinions for this purpose. On a shaft attached to the floor were keyed pinions which worked in racks fastened to spuds hinged near the upper end of

the lower leaf. Thus the leaves could not move without rotating the shaft and simultaneously moving the spuds.

Mr. Martin experimented with racks and pinions at Davis Island, and makes the following suggestion as to their application:*

"On the under side of the upper leaf construct racks of the length of the overlap of the leaves. In the upper end of the lower leaf is a shaft of the full length of the dam, which carries pinions, about 10 ft. apart, meshing into the racks in the upper leaf. These pinions act as rollers to reduce the friction between the leaves. The leaves are united by a sliding link in order to keep the gearing in contact. Experiments made on the rack-and-pinion device with a good-sized model, well illustrate the practicability of the plan to prevent warping of the gate, for, however unevenly the pressure is applied, the gate will rise with a uniformly level crest, but on a dam of considerable size a great risk would be taken, as a stoppage in any one pinion would lock the movement of the leaves or cause a breakage. I am firmly of the opinion that the old style bear-trap, properly proportioned and built in a substantial manner, reducing the leakage to a minimum, is capable of successful use in spans up to lengths from 200 to 300 ft."

Major Marshall has devised an ingenious scheme which he describes as follows:†

"An arrangement of conduits and valves, and a mode of operating the same, by which the supply and exit of water and the resulting pressures within the hydraulic chamber may be differentiated, directed and controlled in such manner that the movements of the gate may be made uniform by the application of adequate pressures at the points requiring them, by varying the amounts of water under pressure and rate of supply, to and from various parts of the hydraulic chamber, thus producing equal or unequal pressures at will over different parts of the hydraulic chamber throughout its extent. Equal and uniform motions of the gate are continued by equal and uniform supply and withdrawal of water under it, and unequal movements of the gate are connected by the application of correspondingly unequal pressures at the proper points of the hydraulic chamber. This is effected by the special arrangement of conduits, orifices and valves by which the hydraulic chamber is divided into aliquot parts by imaginary planes at right angles to the crest, each such part being served by its own conduit communicating at each end through a valve with a vestibule or chamber common to all conduits, which vestibules are capable of being made part of upper or lower pools, either or both.

"When all such conduits are put in communication with the upper or lower pool, the other pool being shut off from the vestibules, water

* *Journal of the Association of Engineering Societies*, Vol. xvi., p. 209.

† Patent Application.

will move uniformly into or from the hydraulic chamber throughout. One or more of the conduits can now be shut off from the vestibules at one or both ends of the conduit, and the movement of the water into or from the hydraulic chamber will then become unequal and the pressures corresponding unequal. Or the vestibules and conduits may be served so that one vestibule may form part of or be in connection with the upper pool and the other vestibule with the lower pool. All or any of the conduits may in this case be put in communication with the entire pool, the other end of the conduit being closed by its valve, and again the pressures may be made uniform or varied throughout the hydraulic chamber.

"The chamber may be divided into any suitable number of aliquot parts and the conduits made to correspond. This arrangement is suggested by the observed and well-known fact that the movements of the gate are dependent upon the actual transfer of matter in contact with it, which matter (water) moves the gate, due to boils, impact, waves or undulations proceeding from near the orifices of ingress or egress in the hydraulic chamber, to more remote parts of the said chamber, in consequence of which the parts of the gate nearest these orifices move more rapidly under the influence of the flow of water through them than more remote parts, and the gate is thereby twisted or warped. The conduits may lead in from each end of the gate because, by allowing inflow and outflow at both ends simultaneously, the capacities of the conduits may be doubled and the arrangement of separate conduits affords facilities for flushing or scouring out each separate conduit in succession or separately without materially disturbing the stability of the dam. By placing the vestibules, one in connection with the upper level, while the other communicates with the lower level, any one of the conduits may be placed in communication with the lower level and a current sent through it, all conduits being at the same time in communication with the upper level—thus supplying a vastly greater quantity of water than the amount withdrawn."

The proper construction of the gates so that they will not warp or twist, no matter how or where the power is applied, is probably the best remedy for this defect. This will require a very rigid construction and possibly an expensive one, but it is sure to be successful.

(2) *Initial Head.*—The second problem, that of starting the gates, has been solved by the introduction of an auxiliary dam of another type; but, as this necessitates a double construction, engineers have been trying to hit upon a better solution. With the most sensitive gate it is evident that some head will be required to overcome friction, sediment, débris, etc., and the excess in weight of the gates themselves. It is quite easy to secure a head where the bear-trap is lo-

cated in a pass of higher level than that used for navigation, because the deeper openings can be closed first; but how can this head be obtained where the navigable pass itself is to be closed by this form of gate?

In the bear-trap weirs of Dam No. 6, on the Ohio River, it is proposed to experiment with raising by the use of compressed air, as stated elsewhere in this paper. This will require the construction of a special plant at considerable expense. The author is of the opinion that the necessary head can be best and most economically obtained by the erection of a low auxiliary dam which can be raised from the masonry. A dam of light, A-shaped trestles, 1 ft. in width and spaced some distance apart, will partially close the opening and produce the required head. One half of such dam can be raised from the pier and the other half from the lock wall very rapidly. As the head against these trestles would be only such as is required for starting the gates, it is evident that they may be very light, simple channels or planks.

A dam in use at La Neuville, France, on the River Marne, which has a sluice closed by bear-trap gates, which are raised by securing a head with the counter-shutters of Thenard, is described as follows:

The width of the sluice is 29 ft. 8 ins. The sill is 3 ft. below low water, and 9½ ft. below the level of the pool. This sluice is provided with a series of Thenard counter-shutters above the bear-trap dam. To close the dam the counter-shutters are raised, shutting off all water from the bear-trap. The down-stream valves of the culverts are shut. The up-stream valves remain open. The difference in level creates pressure under the gates, and the gates rise. The water now overflows the counter-shutters, and they are lowered.

To lower the dam the up-stream valves are closed, and the lower ones opened. The water under the gates escapes through the culverts into the lower pool, being forced out by the weight of the gates which finally lie flat. The time required to lower the gates is three minutes. A fall of 2 ft. is necessary to induce the gates to rise, and the time required to secure this much head must be added to the maneuver of raising the gates. The great weight, and the fact that they revolve around an axis at the end, creates a moment of resistance to be overcome of 35½ lbs. to the square foot at the instant the dam begins to rise. The wooden axle causes too much friction. If this is reduced, the leakage becomes of too much consequence, reducing the pressure.

The Neuville dam cost $13 603 or $469.07 per running foot, an enormous expense. De Lagrene says these facts render inexpedient a dam possessing many virtues and some ingenuity.

(*3*) *Application to Wide Passes.*—Bear-trap dams may be applied to wide passes in the manner previously indicated of dividing the dam into aliquot parts having independent conduits, or by independent units or sections separated by partitions permitting independent movement, but having a single conduit; or each section may have its own supply pipe and thus become an independent gate. It is not necessary to further describe the first method, but a brief outline of the second as proposed by Major Marshall is given, as follows:

"The dam to be in sections of approved length, each alternate section to be an abutment section formed by suspending from the longer lower leaf a thin metal or wooden diaphragm closing the ends of the abutment section, raised and lowered with this section, out of and into a narrow pit through a slot protected against entrance of sand and gravel. This diaphragm serves as abutment to close the ends of adjacent sections when they do not rise faster, or do not fall less rapidly than the abutment sections to avoid warping.

"In rising and falling each section controls its neighbor by automatically diminishing the 'effective' head of water actuating the higher section, so that all sections must rise or fall quite, or nearly at the same rates. Otherwise, each section is an independent gate, communicating through its own ports with the regulating reservoir through the conduit.

"The gates are made of metal as heavy as required by the necessary strength, and an initial head to partially raise the gate until an upper pool is formed, is arranged for by constructing a small reservoir on the bank with level above ordinary high water; this reservoir to be kept in readiness for use by pumping water at intervals into it from the river. This reservoir communicates through pipes with a regulating reservoir, which includes also a capacious conduit or communication with the hydraulic chambers under the gates. The regulating reservoir is for regulating the initial head or pressure to be applied to partially raise the gates, which head should not exceed one-half the lift of the dam, and can be regulated to gauge by the valve controlling the inflow. This regulating reservoir communicates also by means of capacious valves with the upper and lower levels at the dam, by means of which the inflow and outflow of water to the hydraulic chambers may be regulated.

"The conduit, or communication leading from the regulating reservoir to the hydraulic chambers, is made so capacious that there shall be no diminution of head due to friction. The inlet ports between this

conduit and the gate chambers are pipes. The outlets must be many times larger than the inlets, to allow the water to be pressed out by the weight of the gates when nearly down, which is accomplished by flap valves moving freely outwards from the hydraulic chambers into the conduit when the gates are lowered, but not inwards or from the conduit when the gates are raised. All chambers then are supplied with restricted inlets of equal dimensions under the same head, and with outlets of greater capacity.

"Arrangements are made for flushing or scouring deposits from the conduit. The inlets and outlets in capacity are inversely proportional to the velocities due the effective heads of water, the weight of the gate being assumed as equivalent to 6 ins. head.

"Whenever any section moves upwards more rapidly than its neighbor, or downwards more slowly, automatic valves are opened by its neighbor to diminish the pressure or head under it, which will cause all sections to move nearly at the same mean rate and keep in level in rising or descending. This will result in little or no lateral pressure on the diaphragms or abutment sections due differences in head on the two sides, and consequently but little friction will be experienced at the slots. Rollers are supplied to diminish this friction.

"The slots may be so protected by flaps that nothing coarser than muddy water can enter, and the pit may be readily kept clean by connecting its bottom with the conduit, so that whenever the dam is worked, the sediment may be stirred up and withdrawn."

Remarks.—Some two years since the author submitted a sketch of a bear-trap dam to the engineer officer in charge of the district, the late Colonel Gregory, in which it was proposed to introduce the water at intervals under the dam, through perforated pipes leading out of chambers built in the up-stream part of the foundation; each pipe being controlled by a valve, so that the supply might be regulated at will as the necessities required. The outlets were also governed by valves. Lateral pipes were connected with the main conduits, so as to fully distribute the water, the orifices in which became more frequent as the distance from inlet and outlet increased, the object being to discharge an equal quantity of water under all parts of the gates. The chambers out of which the conduits opened were covered by Thenard counter-shutters, having gratings hinged at the up-stream wall of the chamber. When the shutters were raised, the free ends of the gratings also came up, and, while permitting a copious flow of water into the chambers, prevented the entrance of drift and débris. The shutters were started upward by pressure from an accumulator, or by special mechanism operated from the lock wall, when the current completed

the raising. They were prevented from becoming vertical by the grating mentioned. The raising of these shutters contracted the waterway and formed the initial head required to start the bear-trap gates.

The several chambers communicated with each other and with culverts in the pier and lock wall, so that after the bear-trap was up the chambers were closed at the top and received their supplies through the wall valves, which were of small size, and not capable of filling the chamber rapidly when raising the dam. Each set of valves worked independently or simultaneously, as desired, by levers attached to rods in the culverts connecting the chambers for the filling valves, and by similar mechanism in a conduit for the discharge valves.

Lift Dam.—Water may be applied to assist in raising a dam in the following manner:

In the foundation are constructed a number of wells, or a trench, in which float hollow cylinders, or a water-tight caisson. On these cylinders, or the caisson, is constructed a suitable framework, on which the leaves of the dam rest, and their buoyancy is just such as will counterbalance the weight of the framework and dam when down and the water at a certain depth. An increase of the depth of water over them when down simply settles them and the framework on the foundation. A decrease will cause them to rise, as will also the application of power.

Drum Dams.

Desfontaines.—M. Desfontaines, Chief Engineer of the Marne River, in France, invented what is known as the "drum" wicket about 1860. It has had wide application upon the weirs of Chanoine dams. These wickets are $4\frac{1}{2}$ ft. wide and $3\frac{1}{4}$ ft. high above the sill, and revolve on a horizontal axis, which divides their height into two nearly equal parts, the lower of which turns in a semicylindrical recess in the masonry, or of iron sunk into the foundations. By establishing communication between this recess and the upper pool, the dam is raised; and by connecting it with the lower pool, it is lowered. All this is done by the turning of a plug on the bank.

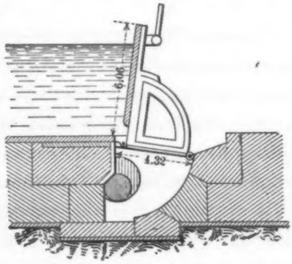


Fig. 8.

Dams of the Main.—This system has found great favor in Germany, where the dimensions of the wickets have been greatly increased, and at Schweinfurt there were built, in 1873, on the Main, wickets 31½ ft. wide, supporting a head of 5.90 ft. on the sill. The under shutter is placed at right angles to the upper one, and not in the same plane. In Prussia there was built, in 1880, on the Kuddow River, a pass in a mill dam, the wickets of which are 17 ft. wide and 5.90 ft. above the sill. In 1884 there was put in on the Spree, just below Berlin, a pass 32½ ft. wide, and having 9.18 ft. on the sill. This wicket is, therefore, 18.36 ft. wide (Figs. 9 and 10). In 1886 there were built, on the Main, passes 39.4 ft. wide, which have 5.6 ft. on the sill. These dams can be opened under full head by the moving of a lever, and immediately raised against the rush which follows.

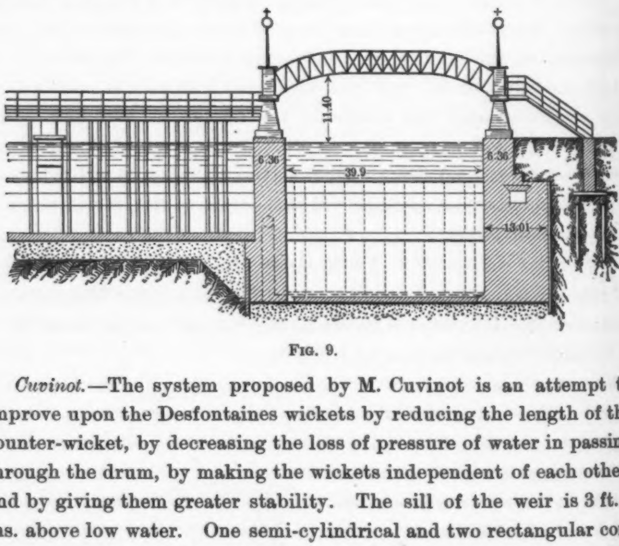


FIG. 9.

Cuvinot.—The system proposed by M. Cuvinot is an attempt to improve upon the Desfontaines wickets by reducing the length of the counter-wicket, by decreasing the loss of pressure of water in passing through the drum, by making the wickets independent of each other, and by giving them greater stability. The sill of the weir is 3 ft. 3 ins. above low water. One semi-cylindrical and two rectangular conduits are built into the masonry. The up-stream one is connected with the upper pool, and the lower one with the lower pool. The middle is divided by a diaphragm into compartments of the length of the wicket and supporting the axis of the counter-wicket. The two arms of the counter-wicket are prolonged into props provided with friction rollers. The diaphragms also support the axes of the wicket.

Each compartment communicates with the upper conduit by a hole which always remains open. They are put in communication with the lower conduit by the operation of a valve.

When the pressure turns the counter-wicket, the props take the wicket in reverse, making it describe an angle of 70 degrees. Supposing the dam down, and the valves connecting with the lower conduit closed, there is an equality of pressure on each face of the counter-wicket. When the valve is opened, the pressure face is relieved and the wicket is set up. The valve is now closed, and the equilibrium is reinstated. The wicket presses on the rollers and carries the counter-wicket back to its first position as it falls down itself. In order to permit this lowering, it is necessary to have water communication be-

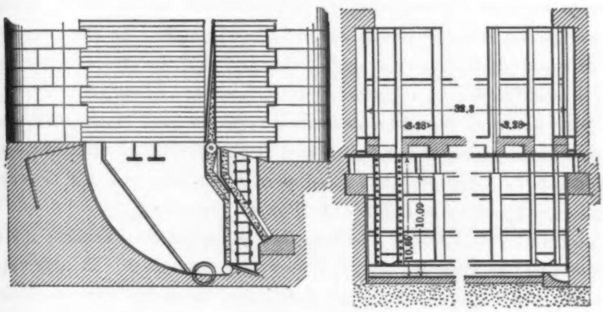


FIG. 10.

tween the two faces; that is, the counter-wicket does not make a water-tight connection, but permits leakage, so the only maneuvering necessary is that of the valve. The compartments render the operation of each wicket independent of all others. The raising is done in reverse order. In a dam such as that of Joinville, the counter-wicket is 8 ft. 2 ins. below the sill. By this system the depth would be decreased by 2 ft.

Chittenden.—The project for the improvement of the Osage River by the construction of a movable dam of the drum type invented by Captain H. M. Chittenden, U. S. Engineers, has been approved. The proposed dam is thus described: The dam rests on a pile foundation surmounted by a timber grillage on which rests a water-tight floor

of 4-in. plank. The second row of piles on the up-stream side consists of triple thickness sheet piling reaching entirely across the river on a line with the sheet piling under the lock. It extends downward to reference 75 ft., and will cut off the under flow of the river for 25 ft. beneath the river-bed. The foundation of the dam proper is 25.5 ft. broad, and the structure forming the apron of the dam, also resting on piles and joined to the main foundation, is 16.5 ft. wide, giving a total breadth of base of 42 ft. (Figs. 11 and 12).

The greatest possible relief of the dam, or difference in elevation between the upper and lower pools, is 16 ft. This, however, as explained in the discussion on the strains of the gate, can very rarely occur. In fact, when the present work of opening a direct connection between the Osage River and the Missouri, near Cote sans Dessein, is finished, the lower pool cannot fall below 105 ft. during the navigation season, giving a relief of only 11 ft. In the preparation of these plans, however, and in determining the strains upon the gate, a possible maximum relief of 16 ft. has been assumed.

Upon the foundation just described rests an iron framework consisting of two parts, *MLNOPD* and *DEFG*, which, with the concrete mass *HIJK*, forms the fixed weir. The frames *DEFG* occur every 5 ft. The frames *LMNOPD* occur every 2½ ft.

The frame *LMNOPD* forms the lower wall of the chamber *AZQ* and sustains the pressure on the concave surface *D′Q*. It also supports the upper end of the apron *RR′*; and when the gate is closed for repairs, it supports also a part of the weight of the gate and the pressure on the bulkhead *VWX*. The frame *DEFG* supports the movable part of the dam and forms the upper wall of the chamber. The wooden partitions *D′Q* and *E′Z* are water tight. The concrete mass *HIJK* forms the impervious barrier of the fixed weir and supplies the weight necessary to the stability of the whole structure.

The apron of the dam, like the main structure, rests upon piles, and is not liable to undermining from the agitation of the water below the dam. The space beneath it is left vacant, except as filled with back water from below, or with the sediment that may collect there. The escape of water from the chamber at *Q*, and from the interior of the gate at *B*, passes into this space. The superstructure, or movable portion of the dam, is a sector of a circle in cross-section. The arc

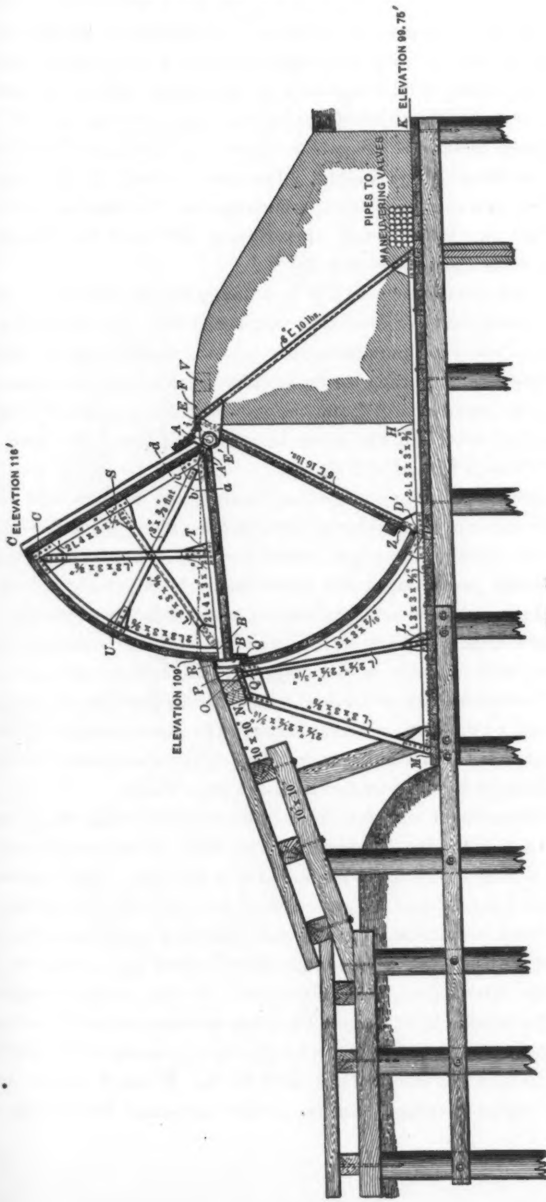

ELEVATION 116'
ELEVATION 109'
ELEVATION 99.75'
PIPES TO MANEUVERING VALVES

FIG. 11.

subtended is 67 degrees 30 minutes. It consists of an interior iron frame-work $A'B'C'$, with a wooden exterior $A\ B\ C$. The upper face $A\ B$ is air tight. The lower face is water tight, and the cylindrical face is air tight about two-fifths of the distance from C to B. The ends of each section of the gate are closed, and air tight from C down about one-third of its height. The gate is held by the hinge A. When the gate is in operation, it is supported by water pressure and by the pin A. When not in operation, it falls into the chamber $A\ Z\ Q$ and rests against the stop Z.

The triangular space $D E H$ is a longitudinal culvert by which water is conveyed to or from the chamber $A\ Z\ Q$. In order that the pressure of the water may be applied to, or withdrawn from, the face $A\ B$ of the gate, uniformly throughout its entire length, the connection between the chamber $A\ Z\ Q$ and the culvert $D\ E\ H$ consists of a narrow opening $Z\ Q'$ extending the entire length of the gate. Its entire area slightly exceeds that of $D E H$.

The piers separating the sections contain the culverts and valves by which the supply of water to the chamber $A\ Z\ Q$ is controlled. A rectangular culvert 3 ft. x 4 ft. enters centrally from the upper end of each pier and passes out at the lower end. It is intersected at the center of the pier by a cross culvert of trapezoidal cross-section, but of the same area. A heavy iron girder, imbedded in concrete at the ends, cuts both culverts in two diagonally at their junction, so as to restrict communication through the up-stream culvert to the chamber to the right of the pier, and that through the down-stream culvert to the chamber to the left of the pier. The culverts are closed by sliding valves operated by oil cylinders actuated from shore.

The operation of the gate is as follows: The outlet valve being closed, the inlet valve is opened. The head of the upper pool is brought to bear on the lower surface $A\ B$ of the gate. There is always a sufficient head to raise the gate, except in a certain contingency to be considered further on. As the gate rises and approaches its normal position when up, it is not brought to rest by a stop, but by closing the inlet valves, or, automatically, by the escape of water at Q'. $R\ Q$ is a grate $2\frac{1}{2}$ ft. long. There are seven of these to each section. Their combined free space for the flow of water is about 10 sq. ft. The area of the inlet culvert is 12 sq. ft. When Q' passes above Q, water begins to escape, and the outflow increases the farther the

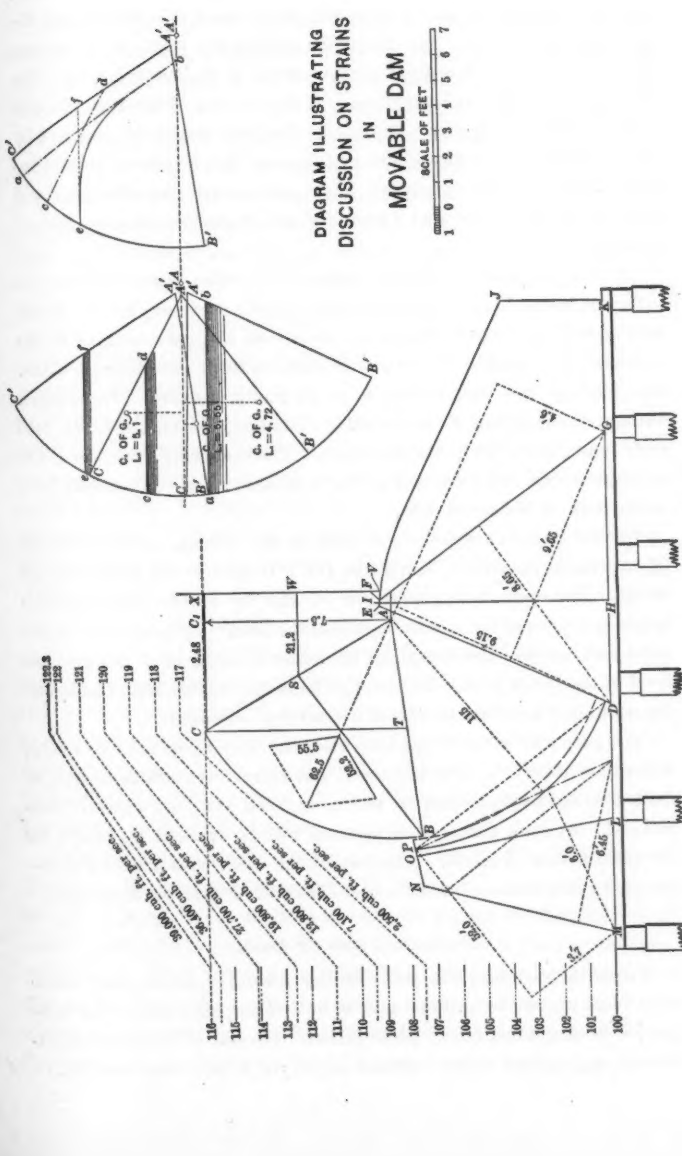


DIAGRAM ILLUSTRATING
DISCUSSION ON STRAINS
IN
MOVABLE DAM
SCALE OF FEET
C. OF G.
L = 5.1
C. OF G.
L = 5.55
C. OF G.
L = 4.72
2,500 cub. ft. per sec.
7,100 cub. ft. per sec.
13,800 cub. ft. per sec.
19,800 cub. ft. per sec.
27,700 cub. ft. per sec.
30,400 cub. ft. per sec.
39,000 cub. ft. per sec.

FIG. 12.

gate rises. By the time Q' reaches R, the outflow through the grate, with the leakage at other points, will fully equal the inflow, and the gate will cease to rise. By gradually closing the inlet valve, the gate will settle back to its normal position when Q' is just below Q. The valve is then left in this position, and the friction of the gate will preserve a balance of forces. Ordinarily the gate would be stopped by the operator when it has reached its normal height, but in case of inadvertence or carelessness no harm can result, for the gate will come automatically to rest without shock or sudden stop, as just explained.

In the contingency already referred to, when there will not be sufficient initial head to raise the gate, the air necessary for the expulsion of sufficient water from the interior of the gate to give it the requisite buoyancy to rise in still water is supplied through a 2-in. pipe leading from each section to an air pump on shore. These pipes, with those conveying oil to the valve cylinders, are buried in the concrete mass, as shown in the drawings. The operating room, or house to cover the air and oil pumps, will be located close to the head walls of the lock on the shore side.

For the purpose of making repairs to any section, a bulkhead may be erected, supported by the frame $DEFG$, and by the gate, through struts. The gate is supported at A, and by braces resting on the apron and against the circumference of the gate. By closing the upper valve and opening the lower, the structure is uncovered down to the level of the lower pool. By closing the lower culvert also, and applying a pump, the entire structure is rendered accessible.

The gate will never be kept up after the upper pool reaches a stage 4 ft. above its crest. The piers will not form obstructions to drift, as drift does not begin to run in the river until they are entirely submerged. At such times, their location will be marked by buoys, for the information of pilots. The cost of the dam, with a liberal allowance for every item, is a trifle under $120 000, or $140 per lineal foot.

Various Types of Dams.

Under this heading will be collected several types of dams which have come under the author's notice, but which have not, so far as he knows, been applied to any great extent. Several of them contain excellent suggestions to the engineer employed in this class of work.

Petitdidier Dam.

This dam, proposed by S. Petitdidier, consists of a solid dam of wood, 3 ft. wide and 6 ft. deep, well fastened together with irons and moving up and down in a cavity with vertical sides provided with friction rollers, the motive power being heavy counterpoises at each end. The counterpoises were so hung that in high water they were submerged and their loss of weight, thus occasioned, caused them to rise and the dam to descend into its chamber automatically, thus opening the pass. When the water falls, the counterpoises again raise the dam. A crib is built around the counter-weights for their protection.

Krantz Wickets with Pontons.

This system, the invention of Chief Engineer Krantz, was first proposed in 1868, and is in use in the Port Villez dam. It consists of a lockette and dam proper, which includes pontons with upper wickets and valves, and a water conduit. The dam is raised and lowered by pontons. A ponton is a hollow, rectangular body built of sheet iron, and water tight. It floats in the conduit, and swings from hinges near the top of the down-stream side of the conduit. At its upper upstream corner the wicket swings. The Port Villez pontons weigh 14 405 lbs. and displace 21 839 lbs. of water. They therefore tend to rise with a force of 7 434 lbs.

The section of the dam may be 30 ft. long. There must be a lockette at each end of each section. The lockettes are large iron boxes, connecting by valves with the upper and lower pools, and, by an opening, with the conduit, which they furnish with water. A conduit, trapezoidal in form, extending 8 ft. 7 ins. below low water, runs the whole length of the dam. It distributes the water of different pressures to all parts of the dam.

When the dam is down, the ponton is submerged in the conduit. The wicket lies flat and covers it. The moment of buoyant effort of the ponton is rendered sufficient to raise the ponton by the pressure of water turned into the conduit by way of the lockette from a reservoir on the bank. This reservoir is filled from the upper pool when the dam is up. The ponton rises in proportion to the amount of water turned into the conduit. As the ponton rises, the wicket emerges from the water, and the flutter-valve in the chase swings open. This causes

the greatest water pressure on the breech, and the wicket swings to an upright position and the flutter-valve closes. To prevent the pontons from rising too high, or to lower the dam altogether, the down-stream valve of the lockette is opened. To cause it to rise higher, the upper valve is opened, so that the level of the pool may be regulated at will by the valves.

For this dam it is claimed that it is easily and speedily controlled by human agencies; that it automatically corrects variations in level, rarely requiring attention; that the parts are strong enough to resist any shock; that it is tight, applicable to high lifts, and operated by the aid of natural forces.

Brunot Dam.

This dam, invented by the Hon. F. R. Brunot, of Pittsburg, is similar to the Krantz dam in that a hollow ponton is the active principle of the plan. The ponton is as long as the opening in the dam, with proportionate width and depth. The ponton fits into a chamber in the permanent portion of the dam, and a space or conduit is left underneath the ponton, into which the water of the upper pool is allowed to flow when it is desired to raise the dam, and from which the water escapes into the lower pool when it is necessary to lower the dam. When the ponton is down, its top is even with the floor of the dam. The ponton is hinged at its upper up-stream angle to the up-stream edge of the ponton chamber. A shoulder fits over this hinge to keep out débris.

Mr. Brunot suggested two means of operating his dam. The first was to raise it by pressure under the ponton, caused by connecting the upper pool with the conduit, and to lower it by shutting off this connection and opening the valves into the lower pool, allowing the water to escape, and shutting off the pressure from above.

His second and better plan was to fill the ponton with water by the manipulation of a valve when it was desired to lower the dam, thus sinking the ponton and removing the obstruction to the current; and when it was desired to raise the dam, to pump out the ponton, thus allowing it to rise in the chamber by virtue of its buoyancy. The ponton can be pumped out by the use of a turbine wheel in a well in the abutment, turned by the pressure of the water of the upper pool.

Dechant Dam.

The dam of Wm. H. Dechant, C. E., of Philadelphia, consists of an improved wicket or flushing board, intended for the pass of the weir and for the comb of permanent dams. It is chiefly useful as a conservator of the water supply in hot and dry weather.

The wickets are of great length, and are supported by tension hinges, instead of props, attached at one-third the height of the wicket. The wicket carries a revolving bar to which are fastened holding bars. These secure the steadiness of the wickets. A notch at the end of the wicket prevents the revolving bar from turning. When it is desired to lower the wicket, the revolving bar is forced endwise beyond the notch, when it revolves. The holding bars then drop down and the wicket falls down stream by the pressure of the upper pool. The hinge being at one-third the height, the water catches the chase when the wicket starts to rise and assists in lifting it to a vertical position.

The maneuvers are performed from a caisson-operating truck which rolls on rails, one above and one below the wicket; so that the dam-tender stands directly over the wicket. This truck should be made of iron, as it will then present less resistance to the water. "It is practicable and desirable," says the inventor, "to use steam power on the truck, as this will render maneuvers rapid."

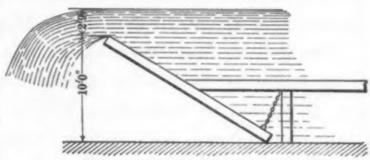


Fig. 13.

Self-Acting Weir, River Irwell.

Across the River Irwell, in England, near Manchester, is a self-acting weir of peculiar construction. A series of shutters turning on a central horizontal axis 12 ft. in width across the river, 10 ft. wide above the axis, and 9 ft. below, having a total vertical height of 10 ft. above the floor are opened by the water when it rises 2 ft. 9 ins. above the crest. The shutters are inclined at an angle of 35°, and revolve to a horizontal position when open. A system of chains attached to the bottom of the shutters or wickets, and leading to crabs on each bank, may also be used for opening. The dam has 14 wickets, and was designed by Mr. Wiswall (Fig. 13).

Stickney Dam.

This dam, designed by Lieut.-Col. Amos Stickney, U. S. Engineers, consists of a series of structures standing upright in a recess in the masonry, when not in use, and capable of being lifted up by the introduction of water pressure in the recess, so as to shut off the flow of a river and form a dam. It is fully described by its designer in the *Journal of the Association of Engineering Societies*, Vol. XVI, p. 255.

Trestle Dam.

In this design the author has attempted to avoid the use of needles, gates, planks or curtains in a trestle dam, and relies wholly upon the trestles themselves for the retention of the water, as well as for the support of its pressure. The trestles may be raised and lowered precisely as are other trestles, or with a special arrangement similar to that used on the needle dam on the Big Sandy River at Louisa, Ky.

Description.—The dam consists of a number of A-shaped trestles set up adjoining each other across a stream, the up-stream faces or legs of which, in connection with a sill, which also protects the trestles when down, hold back the water. The two legs of each trestle are connected at the top, where they are placed close together, and at the bottom they terminate in eyes which are connected by pins to journal boxes attached to the masonry. Horizontal braces may connect the two legs at intervals, being placed on the side of the trestle which is next the masonry when lying down, and these may be so constructed as to fit in between the legs of an adjoining trestle when up, thus forming a brace to both sides of the frame; but the author would not recommend this construction, preferring to so build the trestles that they will stand all strains without assistance from bracing of any sort (Fig. 14).

The up-stream member of each trestle is a frame of channels suitably arranged and covered with plates riveted on. The edges of these plates touch each other on adjacent trestles when standing, and may either extend slightly over the channels, or the latter may be set flush with flanges toward each other. The latter construction gives a thicker wall through which the water must pass in leaking. Wood may be inserted in the back of the channels when exceptional tightness is desired. The down-stream post may be similar to the up-stream one,

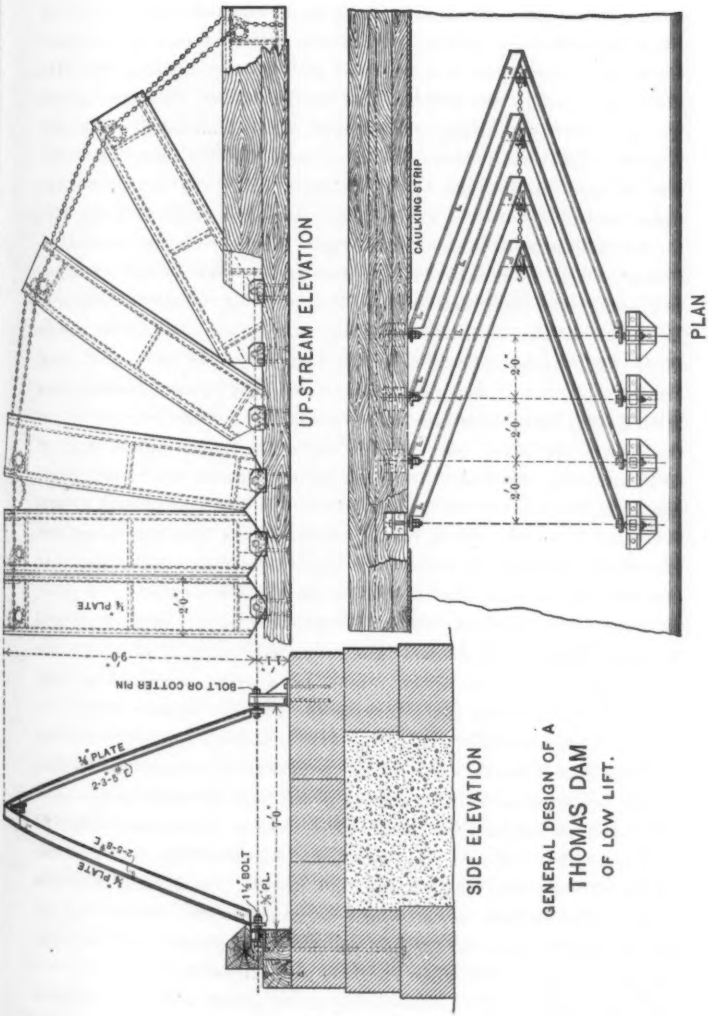

UP-STREAM ELEVATION
CAULKING STRIP
PLAN
SIDE ELEVATION
BOLT OR COTTER PIN
¼" PLATE
1¼" BOLT
⅜" PL.
2'-0"
9'-0"
7'-0"
GENERAL DESIGN OF A
THOMAS DAM
OF LOW LIFT.

Fig. 14.

or it may be latticed, or even consist of a single member like the prop of a wicket. At the bottom of each post a piece with an eye, bent so as to have the part containing the eye stand vertical, is riveted to the frame, and these are connected by pins to journal boxes on the floor. These boxes have their eyes centered at a greater distance from the floor than one-half the width of the trestle face, so that the trestles may turn without binding. The upper box is imbedded in the sill. A space is left open between the lower boxes for the escape of water, and to assist in keeping the floor clean. The sill closely fits the upper face of the trestles at the point where the angle is made with the eye-pieces, so as to prevent leakage. An idler can also be introduced here, if desired, for this purpose and to prevent the collection of gravel. The construction may be such as to permit overflow, as in wicket and gate dams, or a walkway may be provided as in needle dams. In the latter case a simple leaf hinged to the top of each trestle, and when in use opening up stream, may be used in connection with the top of the trestles. When not in use it folds over the top of the trestle, out of the way. As the top of the trestle will be from 12 to 18 ins. wide, the hinged walk can be very narrow, the trestle itself answering for most of the walk required. In the head of each trestle is located a sprocket wheel for use in connection with the maneuvering chain. This wheel turns on a shaft attached to the frames. At one edge of the wheel and forming a part of it is a ratchet. A pawl, having a tooth which may fit loosely into this ratchet at one end, and have the opposite end formed into a rounded wedge, is pivoted so as to be readily lifted out of the ratchet by depressing the wedge end. This depression takes place just as the trestles become vertical in raising, by the rounded end being drawn under a stop or projection on the adjacent trestle made for the purpose. As long as the trestles remain touching each other this stop will hold the tooth of the pawl out of the ratchet, and the wheel is free to turn. Let a trestle begin to incline or descend, and the pawl, being released from the stop, immediately falls into the ratchet and arrests the movement of the wheel. The pockets in the wheel are made to fit a chain used for raising and lowering the trestles, and this chain cannot move without also moving the trestle when the pawl is in the ratchet.

In addition to the maneuvering chain, which may be connected with or disconnected from the trestles at will, there is, between each

adjacent trestle, a few feet of chain called the fixed chains. These chains are fastened to the trestles by eye-bolts, and their length is determined by the number of trestles it is desired to raise simultaneously—that is, by the power of the crab; but they must be sufficiently long to permit the trestles to lie flat when down. Just above the round end of the pawl on each trestle is riveted a small piece, the purpose of which is to prevent this fixed chain from depressing the end of the pawl, and thus releasing the connection between the trestle and the maneuvering chain. Should this occur, however, through any cause, the fixed chains will still bring the trestles up, so that they can be properly connected with the maneuvering chain.

Maneuvers.—On the lock wall is located a chain crab for maneuvering the pass, and a similar crab is on the pier for the weir. The chains which pass over the sprocket wheels in the trestles come to this crab. The last trestles in the pass and weir are made fast to the ends of the chains.

The methods of lowering and raising are the same for the pass and the weir, and the latter only will be described. To lower the dam the trestle next the abutment is unhooked from the masonry and pulled toward the abutment, the chain being unwound at the same time on the crab at the pier, until it tightens the fixed chain between it and the next trestle and starts that trestle downward. As this occurs, the pawl will engage with the ratchet, and lock the next to the last trestle on the chain. The unwinding goes on continuously, and when the next fixed chain is stretched it will start a third trestle, and so on until all are down.

To raise the trestles the chain on the crab is wound in, bringing up the first one (being the last lowered) and starting several others. When the first becomes vertical and strikes the masonry, its pawl is lifted out of the ratchet by a stop made for the purpose, and thus the trestle is released from the chain without stopping the crab. The continuation of the winding brings up the second trestle which is released from the chain when its pawl strikes the stop on the first. All trestles are thus raised, after the first, by winding in a length of chain equal to that of the short chains connecting the trestles. Where a continuous chain is not used, the trestles may be raised and lowered precisely as are those of wicket and needle dams, each trestle being connected with its neighbor as brought up.

To regulate the pool, in either case, it is only necessary to lower a sufficient number of trestles on the weir next the abutment. In the trestles next the abutment, which are most liable to be used for pool regulation, the fixed chains may be lengthened so as to give less load on the crab in order that the operation of raising may be performed by the watchman alone at night when necessary.

Advantages Claimed.—The advantages claimed for this style of dam over those formed by needles, gates or wickets are:

The dam, being raised and lowered across the current, can be operated either wholly or partially under great heads of water with two or three men.

In raising, the dam is complete when the trestles are up, while in other forms it has but commenced. It is therefore more rapidly raised; the lowering is also more rapid.

There is nothing left standing to catch drift after the lowering begins.

There are no extra parts to care for when lowering or when not in use.

There is no danger to operatives in the maneuvers.

As there is no double construction the foundation is narrow; hence the cost is reduced.

The leakage will be very little as there are few joints.

If submerged, it will act as a fixed dam without injury to itself.

Modified Wicket Dam.

The dam here described was designed by the author several years since, at the suggestion of the late Colonel William E. Merrill, Corps of Engineers, and with his assistance; the object in view being to obtain a dam having all the good points of a Chanoine wicket without the objectionable features of a sliding prop and hurter, and raising against the current (Fig. 15).

Description.—The description accompanying the design is as follows:

"In the modification herewith submitted the axis of the wicket remains the same as in the Chanoine pattern, but the horse and prop are held rigidly together at the top, and each is hinged to the floor at the bottom, thus forming a trestle which, instead of lying down with the current as in the Chanoine type, is lowered across the stream.

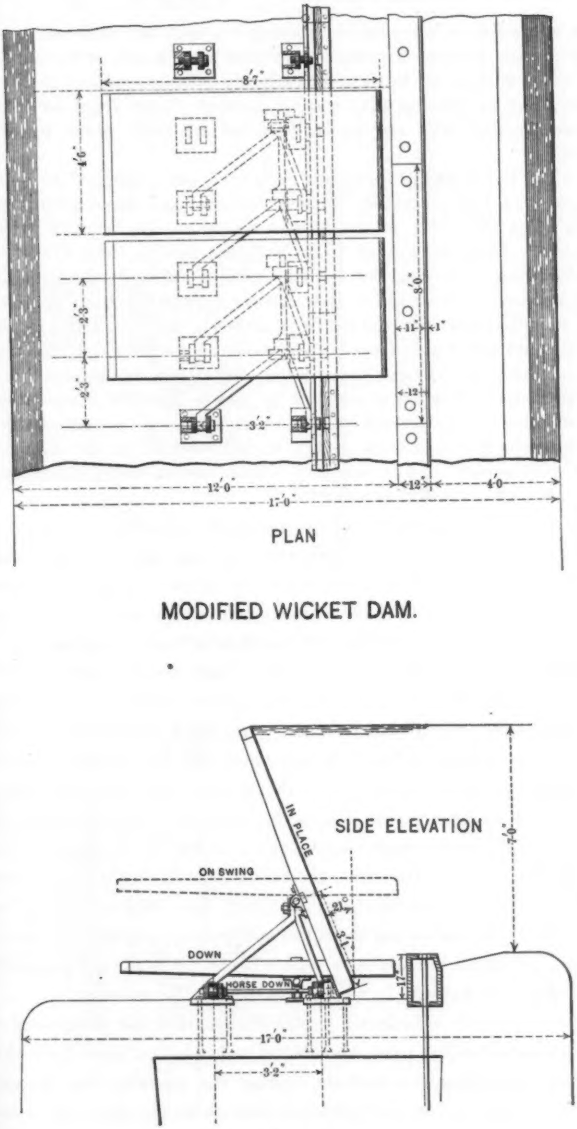

8'7"
4'6"
2'3"
2'3"
3'2"
8'0"
11"
1"
12
12'0"
12"
4'0
17'0"
PLAN
MODIFIED WICKET DAM.
SIDE ELEVATION
IN PLACE
ON SWING
DOWN
HORSE DOWN
7'0"
21°
17"
17'0"
3'2"

FIG. 15.

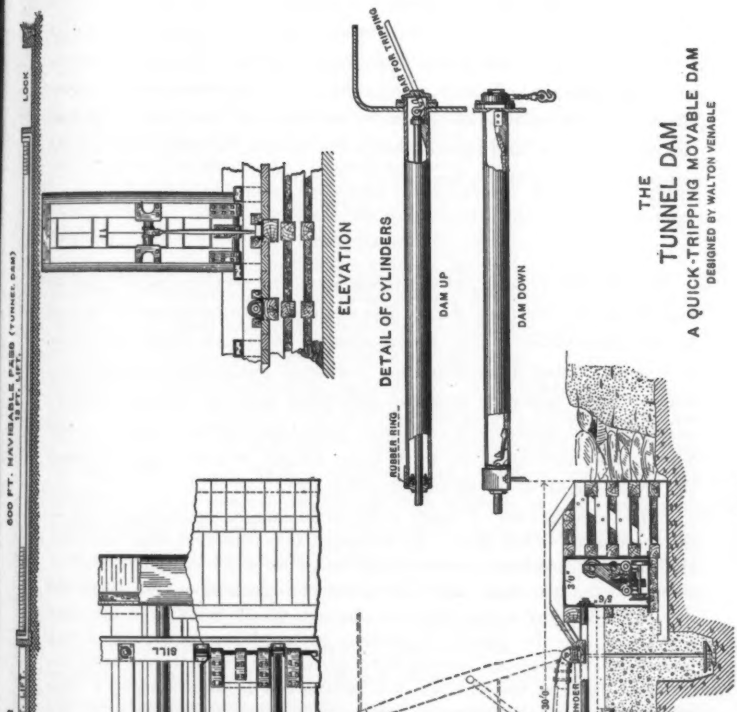
The operation of lowering and raising can thus be performed from the lock or pier without placing obstructing mechanism in the chute.

"The wickets are built practically the same as are those of Chanoine dams, but in placing they may be located closer together than the latter, as they will not be thrown out of their plane by oblique traction.

"The horse and prop, as has been said, are combined in one construction, forming a trestle which is lowered and raised across the current. The lower leg of the trestle makes an angle of 38° with the horizon. There are two of these little trestles to each wicket, their heads being connected by an axle having suitably shaped jaws to receive them. The ends of this axle are turned journals upon which the wicket turns in journal boxes attached to it. The legs of the trestles are made with forged eyes at each extremity, and the trestles are spaced so that when lying down one will be within another. At the bottom the legs are connected by pins to suitable boxes attached to the floor, the up-stream ones of which are made a part of the sill, against which the bottom of the wicket rests when the dam is up. This sill is cast in 9-ft. sections which are securely bolted to the masonry, into which they are sunk."

Maneuvers.—Originally it was proposed to raise and lower this dam by a traveling crane, the wheels of which rolled on rails running parallel to the sill, one above and one below the wickets, but the objection was raised that these tracks would become so imbedded in gravel as to cause derailment. It was then proposed to locate massive hydraulic jacks in the masonry by which the wickets would be pushed down, after having been put on the swing, the pushing of the first one moving all the others, by reason of certain buffers placed between them, until all lost their balance and went down. The raising could be accomplished by the arrangement described for the trestle dam, or by separate chains for each wicket, connected by a man in a skiff, with a rope leading to a crab on the masonry, or by a maneuvering boat. However, the author has no doubt that a traveling crane can be so arranged as to clean the track ahead of itself and work with satisfaction in all the maneuvers, not only of this type of dam, but in the Chanoine as well. It can be either self-propelling, or can move by winding in a rope attached to the masonry.

Advantages.—It is believed by the author that the suppression of the hurter and sliding prop, the ability to lower and raise without the necessity of pulling the wickets against the current, the increased stability of the wicket, the tightness with which the dam can be built



THE
TUNNEL DAM
A QUICK-TRIPPING MOVABLE DAM
DESIGNED BY WALTON VENABLE

Fig. 16.

and the decrease in width of foundation, and consequent cost, are all advantages over the original type.

Disadvantages.—The necessity for putting the pass wickets on the swing before lowering, is, in the author's opinion, a serious objection in all streams carrying much drift, and, although this method is followed extensively in France, the practice in this country is to throw the wickets by pulling up stream on the top until the prop drops into the sliding chute, and then releasing the wicket, in order to avoid the lodgment of drift in the horses.

Tunnel Dam.

Mr. Walton Venable, of the Great Kanawha service, has devised an ingenious shutter dam, which it is proposed to operate from a tunnel in the foundation. His description is given herewith; the term "shutter" being substituted for "wicket" in the orginal in accordance with the generally accepted definition made by Colonel Merrill, in his original study of the subject, that those gates hinged at one edge or end were shutters, while those hinged at some point between the ends should be called wickets (Fig. 16):

"The shutters are of small width (5 ft.) hinged at the lower end to the foundation of the dam. As designed, it is intended that the dam shall be operated from a water-tight tunnel or subway, which may be entered from the lock wall. Each of the shutters which form the dam is held up by a prop, the free end of which rests in a movable seat that may be drawn up stream by applying power to a rod fastened to the seat and passing through a tube which opens into the tunnel. To raise the shutter, the raising rod is connected by a rope or chain to a suitable form of hoist, and is slowly drawn up until the shutter reaches its proper height, at which point a lug on the raising rod falls into a notch fastened to the cylinder and is there held. To lower the dam it is only necessary to raise the lug from the notch with a small bar, and the shutter thus freed will settle into place on the foundation. As a power, compressed air would probably be the best. The ease with which it may be stored and the simplicity of the machinery for utilizing it, recommends it for use about the lock gates, as well as for raising the dam. The arrangement for using a steam hoist would be a very simple one.

"Some of the advantages claimed for the tunnel dam are as follows: The quickness with which it might be raised or lowered; the time required for raising the dam would be reduced to fully one-half that required for raising the Chanoine dam, and the time required for

lowering could be reduced to a few minutes, if necessary. The question of time is often a very important one on quick-rising western rivers. The tunnel dam would be almost free from danger of drift and ice, which give so much trouble in a dam using the swing wickets and Poirée trestles.

"The safety to men employed and the economy in labor are important items in favor of the tunnel dam. The tunnel dam would be much cheaper than the Chanoine, as it is built on the Kanawha, and it is believed that it will compare favorably in cost with those planned for the Ohio, in which the bridge is not used.

"The cost of a tunnel dam, with the depth of foundation shown in the plan, would be about $95 per lineal foot (coffer-dam and excavation not included)."

Remarks.—The return to the principle of Thenard in hinging the shutter at the bottom instead of at some point above is not a backward step, in fact, although it would seem such. In all drift-bearing streams the author believes it to be the correct idea. There is no dam employed which offers so little obstruction to drift when being lowered as one made of shutters. The difficulty with this class of dam has been the great resistance encountered in raising against the current. So long as the power must be applied from a boat or foot-bridge, the shutters must necessarily be of only such width as can be raised with comparatively light machinery. Now that it is proposed to apply the power from a point of safety, with ample anchorage, the ability to raise shutters of immense size need not be questioned. The author has suggested to the inventor the desirability of operating the dam with machinery, outside the tunnel, on the walls, actuating suitable appliances placed in the tunnel; for instance, a shaft carrying chain wheels opposite each cylinder, driven by gearing at the wall, the chains being placed successively in the wheels, those wheels farthest from the power being raised first; or a continuous chain passing through the tunnel, to and from which the raising chains are successively attached and detached, the main chain going over a chain crab at the wall. It is also believed that a system of levers or a tripping bar can be arranged by which the lowering can be accomplished from the walls as rapidly as desired.

Conclusion.

The author desires to apologize for mentioning so many untried devices and ideas of his own. He has originated several types of dams;

either of which he believes can be made successful when properly applied, but he has only described two of these in this paper. Frequent reference has been made to his trestle dam, not because he desires to advertise it for pecuniary advantage, but because he believes it to be the best solution of the problem yet presented, all things being considered. In this he may be mistaken, but an intelligent application of it will be required to settle the matter. Realizing the fact that, as Janicki has well said, there is a "certain legitimate timidity felt by practical engineers at applying on a large scale a system which in its novel combination has nowhere yet been tested," the author has made modified designs of some of the present forms, Chanoine, Thenard, Poirée and Boulé, with a view to their application to higher lifts, and these modifications include devices for raising and lowering the two former and the trestles of the latter from the walls, or from conduits in the foundation. A design for a high-lift, wide-span needle dam, the needles being below or on a line with the lower part instead of above the trestles, applicable to passes of great length, is now under way. He has also devised many appliances for facilitating the maneuvers and bettering the construction of some of the types of dams now in use, including several forms of tripping apparatus for wickets, escapements and methods of placing, for needles, etc., etc. As far as seemed practicable in a paper purporting to describe the new as well as the old, the experimental as well as the approved, the author has refrained from presenting these wholly untried suggestions until they should have a fair test. Many of them may be discarded, after mature consideration, without trial as to their worth or fitness; others may never find the opportunity of application. The object in view has been to suggest certain modifications and ideas with a view to their development by those having occasion to design or construct dams.

If this paper succeeds in bringing out a full discussion of the interesting problems connected with the subject of movable dams, the author will have done all he desires in the matter; for such discussion is bound to develop a sentiment among engineers, legislators, navigators and the general public in favor of the abandonment of the old, obstructing fixed dams, as well as the low-lift movable dams, and the construction of high-lift dams on modern ideas at reasonable cost in the future.

CORRESPONDENCE.

T. C. THOMAS, ESQ.—Some months since Major J. H. Willard, U. S. A., requested the writer to make a theoretical investigation of the Lang gate. Believing that the results obtained will be of some interest to the profession, they are herewith submitted. Mr. Thomas.

In the following investigation of the Lang gate, described on page 542, it is assumed that the head of water on the gate drops with the crest of the gate during the process of lowering, remaining equal to the height of the crest above the base of the gate, or above the lower pool in the case of back-water. This would be true in the case of a limited reservoir above the gate, but is not strictly true in the case of a large reservoir dropping at a reasonable speed. The hydrodynamic effect of the water and the weight of the discharged water on the down-stream leaf have been neglected, as has the weight of the leaves and the friction of the hinges.

FRAME DIAGRAM

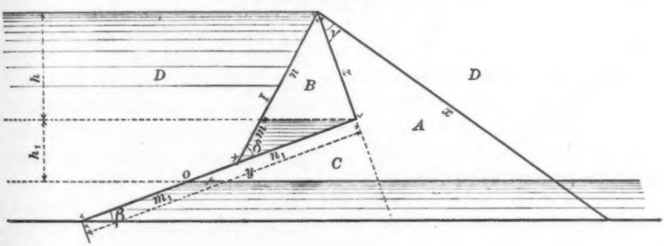


FIG. 17.

Geometrical Relations.—In order that the gate may close flat on the base the following equations must be satisfied:

(a) $x + y - z = 1;$ (b) $y - z = I,$

in which the base of the gate is taken equal to 1, x = length of down-stream leaf; y = length of up-stream leaf; z = length of chains; I = length of idler, all in terms of the base. When the gate is fully raised the height will be equal (numerically) to twice the area of the triangle formed by x, $y + z$ and the base, or height $= 2\sqrt{(1 + z)\, z\, (1 - y)\, y}$. In this expression the factor $(1 + z)\, z$ will be a maximum when z is a maximum; the factor $(1 - y)\, y$ will be a maximum when $y = \frac{1}{2}$. It can be inferred, from a consideration of the equation of forces, that z will in general be a maximum for $y^2 < \frac{1}{2}$. The search for a gate of maximum height can therefore be limited to cases where y has values intermediate between 0.5 and 0.7. Conceive the gate lowered until the chains z are at right angles to the up-stream leaf y (see Fig. 17), then:

Mr. Thomas.

$$\text{(c)} \qquad y = \frac{z \quad (1 - \sin \beta)}{z + (1 - \cos \beta)} = \frac{z \text{ covers } \beta}{z + \text{vers } \beta};$$

$$\text{(d)} \qquad \cot \gamma = \frac{\sin \beta + z}{\cos \beta - y};$$

$$\text{(e)} \qquad I \sin \delta = z;$$

$$\text{(f)} \qquad o = y - I \cos \delta.$$

Let the idler I be divided into the segments m and n by a line through the junction of y and z parallel to the base, and let r = ratio of upper segment to the whole idler, then:

$$\text{(g)} \qquad r = \frac{n}{I} = \frac{\tan \delta}{\tan \delta + \tan \beta}.$$

Equation of Forces.—In lowering the Lang gate the most unfavorable position is that in which the angle δ made by the idler I with the up-stream leaf y is a maximum. This maximum will occur when the chains z are at right angles to the up-stream leaf y. It is proposed to determine under what conditions the lowering and lifting forces will be in equilibrium for this position of the gate. In raising or lowering the gate the idler has a motion of rotation and of translation, and in the general case, neither will exist without the other. Hence, if the idler have equilibrium of translation, the equilibrium of the idler and of the gate will be complete. For equilibrium of translation, the forces acting on the idler must form a closed polygon, irrespective of their points of application; and the algebraic sum of their components in any given direction must be zero. Suppose the gate at the critical position, with back-water at such a height as to leave a segment n_1 of y above back-water. Let h equal the height of the head of water above the junction of z and y (equal $z \cos \beta$) and h_1 equal the height of this junction above back-water (equal $n_1 \sin \beta$) (see Fig. 17).

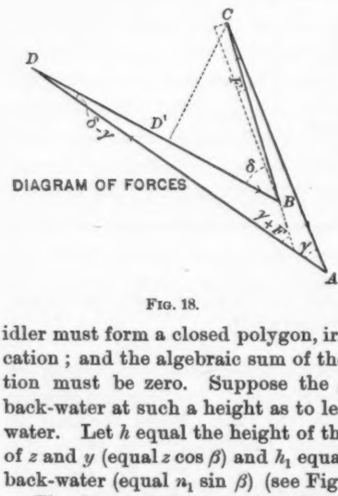


FIG. 18.

The forces acting on the idler are: (*a*) The hydrostatic pressure due to the head h. This force acts normally to the idler and equals $\frac{1}{2} h (2 I - n)$; it is represented in the diagram of forces by $D B$ (see Fig. 18). (*b*) The reaction of the up-stream leaf y on the sliding end of the idler. This force is inclined to the right of a normal to y by the angle of friction F, when the idler is on the point of slipping down y. Its amount can be deduced as follows: The forces acting at the sliding end of the idler are: (1) A portion of the hydrostatic pressure

on the idler equal to $\frac{1}{6} h \times (3 I - \frac{n^2}{I})$, and acting normally to it— Mr. Thomas. represented by $D^1 B$ in the diagram of forces. (2) The compressive stress in the idler acting along the axis of that leaf and represented by $D^1 C$ in the diagram of forces. (3) Reaction of y represented by $B C$ in the diagram of forces. It equals $D^1 B \sec (\delta + F)$, equals $\frac{1}{6} h (3 I - \frac{n^2}{I}) \sec (\delta + F)$. (c) The pull along the chains z is a third force acting on the idler. It is made up of the following: (1) Resolving the reaction $B C$ in directions parallel to y and z, the $\frac{o}{y}$th part of the latter component acts as a pull along z. (2) Part of the hydrostatic pressure on o (see frame diagram) due to the head h and equal to $\frac{1}{2} h \times \frac{o^2}{y}$. (3) Part of the hydrostatic pressure on y due to the head h_1, equal to $\frac{1}{6} h_1 (3 y - 3 n_1 + \frac{n_1^2}{y})$. The total pull along z is represented by $C A$ in the diagram of forces. (4) The fourth and last force on the idler is the reaction of the down-stream leaf x, acting along the axis of that leaf, represented by $A D$ in the diagram of forces. If the several forces on the idler be resolved in directions parallel and perpendicular to x, the component of reaction of x in the latter direction will be zero; and by the condition of equilibrium the components of the several forces in the latter direction will sum to zero. Hence the following equation, in which forces acting upward and to the right are considered positive, those acting downward and to the left negative:

$D B \sin (\delta - \gamma) + C B \sin (\gamma + F) - C A \sin \gamma = 0$. Expanding the sum functions and dividing by $\sin \gamma$.

(h) $D B \cot \gamma \sin \delta - D B \cos \delta + C B \cos F + C B \cot \gamma \sin F - C A = 0$.

Substituting the values of $D B$, $B C$ and $C A$ and dividing by $\frac{1}{6} h$;

(i) $$3 (2 I - n) \cot \gamma \sin \delta - 3 (2 I - n) \cos \delta + (3 I - \frac{n^2}{I}) \sec (\delta \times F) \cos F + (3 I - \frac{n^2}{I}) \sec (\delta + F) \cot \gamma \sin F - \frac{o}{y} (3 I - \frac{n^2}{I}) \sec (\delta + F) \cos F - 3 \frac{o^2}{y} - \frac{h_1}{h} (3 y - 3 n_1 + \frac{n_1^2}{y}) = 0.$$

Assume $n = r I$; $n_1 = r_1 y$. Substituting in the above and replacing o by $y - I \cos \delta$:

$$3 (2 - r) I \cot \gamma \sin \delta + 3 r I \cos \varDelta + (3 - r^2) I \sec (\delta + F) \cot \gamma \sin F + \frac{(3 - r^2)}{y} I^2 \cos \delta \cos F \sec (\delta + F) - 3 y - \frac{3 I^2 \cos^2 \delta}{y} - \frac{h_1}{h} (3 - 3 r_1 + r_1^2) y = 0.$$

Add and subtract $\frac{(3 - r^2)}{y} I^2 \sin \delta \sin F \sec (\delta + F)$, combining

Mr. Thomas. additive quantity with third term; subtractive quantity with fourth term:

(j) $3\,(2 - r)\,I \cot \gamma \sin \delta + 3\, r\, I \cos \delta + (3 - r^2)\, I \sec (\delta + F) \sin F \left(\cot \gamma + \frac{I \sin \delta}{y}\right) + \frac{(3 - r^2)}{y} I^2 - 3\, y - \frac{3\, I^2 \cos^2 \delta}{y} - \frac{h_1}{h} y\,(3 - 3\, r_1 + r_1^2) = 0.$

Assume for cos δ an expansion of the form $\cos \delta = l + k \sin \delta$, and determine l and k by the conditions that expansion shall be true for two assumed angles δ_1 and $(90 - \delta_1)$, then $l = \cos \delta_1 + \sin \delta_1$, and $k = -1$. Substitute $l - \sin \delta$ for $\cos \delta$ in equation (j), z for $I \sin \delta$, and $y - z$ for I:

$3\, z\,(2 - r) \cot \gamma + 3\, r\, l\, y - 3\, r\, l\, z - 3\, r\, z + (3 - r^2)\, I \sec (\delta + F) \sin F \left(\cot \gamma + \frac{Z}{y}\right) - r^2\, y + r^2 z - \frac{r^2\, z^2}{y} - 3\, y + \frac{3\, z^2}{y} - \frac{h_1}{h} y\,(3 - 3\, r_1 + r_1^2) = 0.$

Now, $\cot \gamma = \frac{\sin \beta + z}{\cos \beta - y}$. [See equation (d)].

Also $h_1 = n_1 \sin \beta = r_1\, y \sin \beta$, and $h = z \cos \beta$.

Substituting these values, clearing of fractions, and arranging according to powers of z, except as to fifth term, there results:

(k) $[3\, y\,(2 - r) + (3 - r^2)(\cos \beta - y)]\, z^3 + [3\, y\,(2 - r) \sin \beta - r\, y\,(\cos \beta - y)\,(3 + 3\, l - 2\, r)]\, z^2 + y^2 (\cos \beta - y)\,(3\, r\, l - 3 - r^2)\, z + (3 - r^2)\, I \sec (\delta + F) \sin F\,(y \sin \beta + z \cos \beta)\, z - r_1\, y^3 \tan \beta\,(3 - 3\, r_1 + r_1^2)(\cos \beta - y) = 0.$

By plotting, in the critical position, a number of gates satisfying the geometrical conditions, it is observed that the junction of the chains z and the up-stream leaf y falls at a nearly constant distance above the base, through a wide range in the relative values of x, y and z. The mean value of this distance is about 0.17, in terms of the base; it equals $y \sin \beta$ (see Fig. 17). It is further observed that the ratio r of segment n of idler above the level of junction, to the whole idler, is a slowly varying quantity with a mean value of about 0.7. In using equation (k) for back-water at or below junction of y and z, assume values of β and give r_1 values from 1 (equals no back-water) to 0 (equals back-water to junction of y and z). For first approximation to z, compute y from the relation $y \sin \beta$ equals 0.17; make r equal 0.70; l equal $\sin 35^\circ + \cos 35^\circ = 1.39$; and neglect term involving angle of friction F. For second approximation, compute y from the relation $y = \frac{z \text{ covers } \beta}{z + \text{vers } \beta}$ [see equation (c)]; I from $I = y - z$; δ from $I \sin \delta = z$; r from $r = \frac{\tan \delta}{\tan \delta + \tan \beta}$; l from $l = \sin \delta + \cos \delta$.

Introduce these values of y, I, δ, l and r, in the general equation, friction term included, and assign value to the angle of friction (made equal to 3° in present discussion). For z in the friction term, substitute the value resulting from the first approximation.

The second approximation will in general be sufficient. For the back-waters from junction of y and z to crest of gate, when at the critical position, the term in r_1 reduces to zero, and the equation becomes: Mr. Thomas.

(m) $[3\,y\,(2-r)+(3-r^2)\,(\cos\beta-y)]\,z^2+[3\,y\,(2-r)\sin\beta-r\,y\,(\cos\beta-y)\,(3+3\,l-2\,r)]\;z+y^2\,(\cos\beta-y)\,(3\,r\,l-3-r^2)+(3-r^2)\,I\sec(\delta+F)\sin F\,(y\sin\beta+z\cos\beta)=0.$

For this equation assign values to r from $\pm\,0.7$ to 0, and proceed in other respects as in the former case.

To express, in terms of the full height of gate, the back-water corresponding to the several values of r_1, we have, calling the height H and the back-water b:

$$\frac{b}{H}=\frac{m_1\sin\beta}{H}=\frac{y\,(1-r_1)\,\sin\beta}{2\sqrt{(1+z)\,z\,(1-y)\,y.}}\quad\text{(See Fig. 17.)}$$

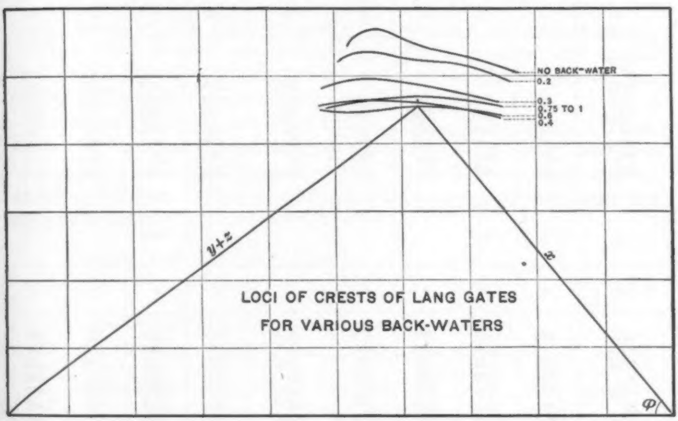


Fig. 19.

And for the case of the back-water above the junction of y and z, at critical position:

$$\frac{b}{H}=\frac{(y\sin\beta+z\cos\beta)-r\,I\sin(\delta+\beta)}{2\sqrt{(1+z)\,z\,(1-y)\,y.}}$$

The values of z corresponding to one assumed value of β are plotted as ordinates with the corresponding back-waters $\frac{b}{H}$ as abscissas, and a smooth curve traced through the plotted points. There will be one curve for each value of β used in the reduction. Values of z corresponding to even tenths of back-water are scaled from these curves. The corresponding values of y can be computed from the relation $y=\dfrac{z\text{ covers }\beta}{z+\text{vers }\beta}$, and x follows from the relation $x+y-z=1$. The

Mr. Thomas. values of x, y and z corresponding to any one back-water and the several values of β, can be used in plotting the locus of the crest of all gates, satisfying the condition of equilibrium for that particular back-water. A number of such curves are appended; they are for gates raised to full height (see Fig. 19).

Table No. 1 gives values of x, y, z, and H corresponding to various values of the angle φ of inclination of the down-stream leaf to the base when the gate is at full height. These values were scaled, or computed from quantities scaled from the above-mentioned curves.

TABLE No. 1.—LANG-GATE PROPORTIONS.

No back-water.					$\frac{b}{H} = 0.2$				
φ	x	y	z	H	φ	x	y	z	H
42½°									
45									
47½					47½°	.715	.512	.227	.528
50	.729	.521	.250	.558	50	.697	.536	.233	.534
52½	.714	.544	.258	.567	52½	.668	.564	.232	.530
55	.672	.576	.249	.550	55	.637	.592	.229	.522
57½	.635	.608	.242	.536	57½	.616	.616	.232	.520
60	.611	.630	.241	.529	60	.590	.640	.230	.512
62½	.585	.655	.240	.519	62½	.564	.664	.228	.500

$\frac{b}{H} = 0.3$					$\frac{b}{H} = 0.4$				
φ	x	y	z	H	φ	x	y	z	H
42½°	.706	.485	.191	.478	42½°	.678	.499	.177	.457
45	.691	.508	.199	.490	45	.651	.529	.180	.461
47½	.670	.534	.204	.494	47½	.627	.556	.183	.462
50	.644	.562	.205	.493	50	.600	.584	.184	.461
52½	.612	.591	.203	.486	52½	.576	.609	.185	.457
55	.584	.618	.202	.479	55	.551	.634	.185	.452
57½	.559	.642	.201	.472	57½	.527	.658	.185	.444
60	.536	.665	.201	.463	60	.505	.680	.185	.438
62½					62½				

$\frac{b}{H} = 0.6$					$\frac{b}{H} = .75$ to 1.0				
φ	x	y	z	H	φ	x	y	z	H
42½°	.660	.510	.170	.446	42½°	.676	.501	.177	.456
45	.632	.539	.171	.447	45	.653	.528	.181	.462
47½	.610	.565	.175	.451	47½	.632	.553	.185	.466
50	.590	.589	.179	.453	50	.611	.578	.189	.468
52½	.570	.612	.182	.453	52½	.590	.602	.192	.469
55	.551	.634	.185	.451	55	.570	.625	.195	.467
57½	.529	.657	.186	.446	57½	.549	.647	.196	.463
60	.510	.678	.188	.442	60	.529	.669	.198	.458
62½					62½				

CAPT. J. G. WARREN.—The automatic water gate, on the Louisville and Portland canal, Fig. 7, page 543, is of the "Modified Parker" type, erroneously called "Lang," and its proportions are in accordance with a mathematical analysis made by Captain H. M. Chittenden, which may be expressed as follows: Mr. Warren.

"Any gate whose leaves fulfill the geometrical condition, lower leaf + lower section upper leaf — upper section upper leaf = base, and whose vertex when at full height does not rise above the curve corresponding to the particular case of back-water considered, will fall under the action of hydraulic force alone."

The maximum angle at the base is 60°; a gate having this angle will, when up, have a section in the form of an equilateral triangle, and, therefore, the most economical form of construction.

The total width of the gate is 40 ft.; the height, when completely up, is 15 ft. 3½ ins.; when raised to this height the down-stream leaf will sustain a load of 154.7 tons, or 3.87 tons per lineal foot of gate.

The sixteen girders composing the leaf are proportioned to this load; no allowance was made for the resistance of the outer skin, the flanges of the girders alone being considered.

The maximum compression is 10.5 tons; the flange section is 3½ sq. ins., at 20 tons per square inch; the flange resistance is 70 tons, corresponding to a factor of safety of 6⅔. The up-stream leaf was designed with a factor of safety of 5. All the wearing parts of bolts and hinges are greatly in excess of this figure.

Weight of down-stream leaf	41 884 lbs.	
" " up-stream "	18 862 "	60 746 lbs.
Displacement of down-stream leaf	67 844 "	
" " up-stream "	2 406 "	70 250 "
Buoyancy		9 504 "

The wickets are operated by hydraulic machinery, as shown in the drawings, the city water at 70 lbs. pressure being utilized. This is regulated by an ingenious 5-way valve, the device of Mr. J. H. Casey, Assistant Engineer. A stroke of this valve in one direction moving the pistons and opening one set of wickets, at the same instant closes the opposite ones; a stroke of the valve in the opposite direction exhausts the water from the cylinders and reverses the above process. The wickets can be so moved that a full stream of water can be set running in a few seconds and this flow regulated or stopped with ease instantly.

The steel shield or gasket, having one end bolted to the outside of the leaf, the other free, moving in and concentric with the quoin, will be forced by the pressure of the water against the hollow quoin and prevent leakage when the chamber is being filled. This shield,

Mr. Warren. originally made of $\frac{1}{4}$-in. steel, was found to be too stiff; $\frac{1}{8}$-in. material was substituted and fully answered the purpose.

The flap, or idler, at the lower end of the up-stream leaf prevents leakage into the chamber when the gate is being lowered. The pipe line leading from the shaft, and connecting the different compartments, is for the drainage of leakage from the lower leaf and for letting water into the interior of the leaf, should it be necessary to increase the specific gravity of the gate.

The difficulty with gates of this general type hitherto constructed, has been that they did not fall. As far as the theoretical solution is concerned, the one in question should be free from that defect; if not, then practically it can be made to fall by the device referred to.

The cylindrical metal floats at the sides of the down-stream leaf have been replaced with flat wooden ones. The unequal rotation at the two ends of the float gate in motion caused twisting and jamming, as should have been foreseen. The pins of the hinges connecting the two sections of the up-stream leaf have been made continuous, it having been found impracticable to keep them in proper line, with the play allowed.

The gate rose and fell without difficulty, and with less than a 6-in. head the first time it was tried.

Mr. Vernon-Harcourt. L. F. Vernon-Harcourt, Esq.—The writer has been much interested in the paper, having inspected several of the French types of dams in 1879, and read a paper on the subject of "Fixed and Movable Weirs" * before the Institution of Civil Engineers in 1880. Again, in 1888, he visited some movable dams in Belgium and Germany, and described them in a paper on "Some Canal, River, and Other Works, in France, Belgium and Germany," † read before the Institution of Civil Engineers in 1889. At an International Congress, held in Paris in 1889, at the request of the organizing committee, he presented a report on "La Canalisation des Rivières, et les divers Systèmes de Barrages Mobiles," in which examples of the principal types of movable dams are shown, drawn to the same scale for the sake of comparison, a system also adopted in "Rivers and Canals." ‡ The present paper consists mainly of descriptions in detail of these now well-known types of dams; and therefore the chief point of interest lies in the description of the author's extension of the needle dam to the maintenance of a greater head of water, on the Big Sandy River at Louisa, than hitherto accomplished; and the formation, at the same time, of a more water-tight dam. This result has been effected by adopting wider and thicker spars than usual for the needles, which are consequently put in place and removed by the aid of a crab and tackle on a barge, which also serves as a

* *Min. Proc. Inst. C. E.*, vol. lx, p. 24.
† *Ibid*, vol. xcvi, p. 182.
‡ "Rivers and Canals," L. F. Vernon-Harcourt, 2d Edition, 1896, vol. i, plate 4.

storehouse for the needles. Another novelty is the form of the trestles carrying the foot-bridge, which are so constructed that when lowered they fit one within another, so that they lie flatter on the bottom, and, being consequently adequately protected by a shallow recess, they are less liable to be covered by detritus carried down the river than the ordinary forms of trestles. The modification in the form of the trestles appears to be a decided improvement, but how far heavy vertical spars for closing the dam are preferable to the Boulé sliding panels, or the system of horizontal planks, remains to be proved by further experience, as sliding panels are more readily put in place or removed, and serve better than heavy needles for adjusting the water-level above the dam. Cameré's rolling-up curtain is very easily worked, and is capable of perfect adjustment; but the greater delicacy of the contrivance might, perhaps, render it unsuitable for rough work in places where it might be difficult to carry out repairs. Mr. Vernon-Harcourt.

In his description of the different types of movable dams, the author speaks of the "Krantz wickets with pontons," on page 559, as in use at Port Villez dam. This is quite a mistake, as when, in 1879, the engineer of the Port Villez dam, M. Cameré, was asked about this system, he replied that some experiments having proved the system to be unworkable, under the existing conditions, the works for it had been abandoned. The author appears to be unaware of the adoption of a hydraulic brake for regulating the rise of the large shutters, with the current of the river, in the Sone dam, which has done away with the injurious shocks to the chains holding the rising shutters of the Thénard system of dam, to which he alludes on page 531, a contrivance fully described by Mr. R. B. Buckley in his paper on "Movable Dams in Indian Weirs," * in 1880. The author states, in describing the drum weirs placed across the timber passes on the River Main (page 552), that "the under shutter is placed at right angles to the upper one, and not in the same plane." In reality, the under shutter, though never placed, in any drum weir hitherto constructed, in the same plane as the upper one, is for the most part approximately parallel to it, and has never been put at right angles to the upper one. Sections of the drum weirs on the Main and at Charlottenburg are shown in the writer's paper of 1889,† and sections of the drum weirs on the Marne in the writer's paper of 1880,‡ which are not correctly given in Fig. 8, page 551, of the paper.

The proposed employment of a drum weir of a somewhat modified type on the Osage River is of interest, as this type is the most perfect form of movable dam, on account of the ease and precision with which it can be raised or lowered to any desired extent. The depth

* *Min. Proc. Inst. C. E.*, vol. lx, p. 43, and plate 5.

† *Ibid*, vol. xcvi, pp. 191 and 192.

‡ *Ibid*, vol. lx, plate 3, figures 2, 3 and 4.

Mr. Vernon-Harcourt.

of foundations, however, necessitated by the drum recess below the dam, makes this system very costly, and has hitherto prevented its adoption for high dams; though in every other respect, except cost, it fulfills admirably the requirements of a movable dam. As a regulating weir for adjusting the water level above, and placed across passes for the passage of timber or drift, it is by far the most suitable form of dam.

The descent of detritus along the river-bed, floating drift, and a very variable discharge are the most serious impediments to the efficient action of movable dams. The first two conditions render the lowering of frames on to the river-bed and the provision of a foot-bridge inexpedient; and the third cannot conveniently be provided against by needles. The bear-trap and the Thénard shutter dam allow of the passage of drift; but they are not well adapted for rapid working, or for regulating the water level. The Chanoine wicket dam can regulate the discharge by butterfly valves in the upper panels of the wickets, and it is readily lowered; but to raise it without the aid of a foot-bridge is a tedious operation. With a foot-bridge, the wicket dam is readily worked, and the discharge can be easily regulated by chains fastened to the top and bottom of the wickets; but the foot-bridge impedes the passage of drift, and under such circumstances is liable to be swept away by a sudden flood, as occurred at the Davis Island dam. It also renders the wicket dam considerably more costly than the needle, panel, or rolling-up curtain dam. Frames hanging from an overhead foot-bridge closed by rolling-up curtains, as at Poses at Port-Mort on the Seine,* answer every requirement of a movable weir except cheapness, as the discharge is easily regulated by the raising or lowering of the curtains, and the hanging frames are readily lifted out of the water from the foot-bridge for the passage of drift, or to open the navigable pass for vessels in flood time. The wide foot-bridge, however, the high piers to give the necessary navigable headway under the foot-bridge, and the long frames hinged to the high foot-bridge render the system expensive.

The author, toward the close of the paper, refers to several proposed forms of movable dam which display considerable ingenuity in design; but it would be difficult to form a just estimate of their merits, until they have been submitted to the test of practical experience. Of the existing types of dams, the drum appears the best for a regulating dam, and for closing passes which have occasionally to be opened for a short time for the passage of timber or drift. The needle dam with improved trestles appears suitable for maintaining a fair head of water in rivers which do not bring down large quantities of drift, and whose discharge does not rapidly vary, while the sliding panel and

* "The River Seine," L. F Vernon-Harcourt, *Min. Proc. Inst. C. E.*, vol. lxxxiv, pp. 234 to 236, and plate 3; and "Rivers and Canals," vol. i, plate 4, fig. 11.

curtain dams afford superior facilities for regulating the discharge, though their complete opening might possibly occupy a longer period than that of the needle dam. Where large masses of drift are carried down, and sudden floods occur, a wicket dam without a foot-bridge would provide the most convenient dam, especially if furnished with improved tripping arrangements. In rivers with beds of shifting shingle, frames hanging from an overhead bridge would furnish the only reliable supports for a movable dam; but such a dam, though costly, could be made of any desired height. Mr. Vernon-Harcourt.

J. P. Frizell, M. Am. Soc. C. E.—The author has rendered an acceptable service to the profession by this *résumé* of the subject of movable dams. The advantages of a movable dam over a fixed one are: That it leaves the channel undisturbed when there is a sufficient depth of water; and that it attempts to control the stream only in its time of weakness, and is withdrawn in seasons of strength and fury, so that it does not require the strength and massiveness of a permanent dam. It secures the latter advantage only when it extends entirely across the stream, and sacrifices it in so far as it consists, in part, of a permanent structure. It has, therefore, seemed to the writer that, if a sufficiently simple, reliable and manageable system of wickets or shutters could be devised, a permanent weir need form no part of such a dam. Neither can the writer understand why so much stress need be laid upon the regulation of the height of the pool. This may in some cases be necessary in the interest of riparian owners; but it is presumed that where the Government has the right to build a dam of given height, in the interest of navigation, it can build either a movable or permanent dam, and in the latter case the height of the pool must take care of itself. Mr. Frizell.

The Chanoine wicket jointed at the center and resting on a horse which can be raised and lowered at will, appears to be the most perfect device yet brought into use for the movable dam. It, nevertheless, leaves much to be desired. Its manipulation requires a foot-bridge with all its attendant attachments. It is erected and thrown down under a head, and requires extra help for these operations which are laborious and dangerous. Both dam and foot-bridge are liable to be fouled by drift in consequence of the numerous articulations under water. Overflow is not admissible.

The writer, while engaged in works of navigation, had occasion to study the subject of movable dams, if not fully, at least attentively, and this subject has since been prominent in his professional studies. He is persuaded that a dam combining all the seven requisites enumerated by the author is not beyond the resources of the mechanic arts. His mind has gravitated toward the idea of shutters hinged to the bottom, which appears to him more likely to secure the desired object than any system of trestles, foot-bridges, needles and wickets.

Mr. Frizell. Probably the solution will be found in some device which has presented itself a thousand times to the mind of every man who has studied the subject, and has been rejected as too simple for consideration.

The Thénard shutters described by the author (page 532), as applied to the top of a dam, worked very well in that situation. How would they work if applied to the bed of a stream as in Fig. 20? In high water both sets of shutters lie flat on the bottom, and are latched down. They are supposed to have buoyancy, so that the free end will rise to the surface if permitted. To raise the dam the up-stream set are unlatched, as near as may be, simultaneously. The ends rise to the surface, and a head is raised which erects them as near as the chains will permit. The interstices between the shutters are stopped in the usual manner, and the total flow of the stream is temporarily arrested. As the water above rises, that below falls, and the point is soon reached at which workmen can wade in and set up the down-stream shutters. When water overflows the up-stream shutters and fills the space between the two barriers, the up-stream set are relieved of all pressure and may be weighed down and latched. There results a barrier consisting of a single line of shutters, which can be tightened by the usual means, and which can sustain an overflow to a moderate extent without inconvenience. A heavy overflow, accompanied by drift, might cause the premature tripping of a shutter. When the time for lowering comes, the dam can be thrown down by tripping the props with the usual devices.

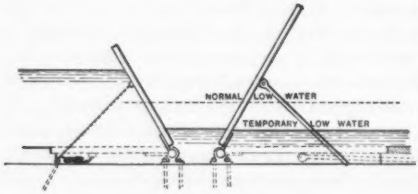


FIG. 20.

Although this method seems very inviting and seductive, it has one defect. After the up-stream shutters are in position, should anything occur to delay the raising of the lower ones, till the water overtops the upper, the whole movement would be blocked, as the upper shutters could not be lowered nor the lower ones raised. This objection is fatal, as the navigation of a stream could not be subjected to such a risk.

The bear-trap gate has found some application in narrow sluices and locks, but none, so far as the writer is aware, to the purpose under consideration, viz., the control of a wide river channel. To confine it to a narrow pass and make the rest of the dam permanent, defeats one of the main advantages of movable over permanent dams, besides incurring the difficulties incident to a very swift current

through the pass, which is at times unavoidable. To give it a length sufficient to close the entire channel is not to be thought of, and to divide the channel into a number of passes by piers is a needless increase of expense. The raising of the dam presupposes a head already existing, implying in the proposed application the means of raising a head independent of the bear-trap, a complication which it is desirable to avoid. Mr. Frizell.

The combination known as the Girard shutter, consisting of a hinged shutter raised against the current by a hydraulic jack, is entitled to careful consideration. It is not chimerical, and would be worthy of adoption if no arrangement less open to objection were obtainable. The cylinders are assumed to lie flat on the bottom and the plungers to move horizontally, being articulated to the props which act on the shutters. The cylinders are all supplied from the same pipe, so that when the pressure water is turned on, the shutters rise simultaneously. Under these conditions the raising of the dam is by no means so formidable an operation as might be supposed, since but a slight head can accumulate during the operation. The dam, after being raised, must be held in position by the pressure of the water on the hydraulic plungers. Any disposition intended to avoid this necessity would introduce new complications into the system, a thing to be avoided by all possible means, as every additional attachment is an additional source of derangement, and an additional risk of failure. This condition necessitates a constant supply of water under pressure.

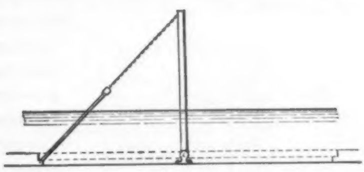
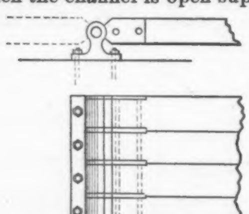


FIG. 21.

The power for pumping would most naturally be obtained from a turbine, in the wall of the lock, which could only run while the dam is up. Even were the power furnished by a steam engine, it could not be expected to keep steam up all the time. An accumulator is, therefore, a necessity. This accumulator must be charged while the dam is up, and retain the charge from the lowering of the dam until the time comes for raising it again, a period liable to extend to many months. This would involve no great difficulty, since the only loss would be from the leakage of the accumulator, the plunger of which might be chocked so as not to rest on the liquid during this interval. Leakage from the plungers of the jacks can only occur while the dam is up and power is obtainable. The quantity of water to be carried in the accumulator, while the dam is down, need not be sufficient to fully raise the dam, but only to raise it enough to create a working head for the turbine.

Mr. Frizell. In this system some trouble is to be apprehended from frost, as the dam might require to be lowered after the temperature of the water had fallen to 32 degrees. In this condition ice often plays strange freaks. Mush ice accumulates on stone, wood, or metal below the surface of water, where no ice occurs on the surface. It might form in the cylinders, though several feet below water, and, being compressed by the plungers, prevent the dam from being fully lowered. This difficulty could not occur in raising the dam, and should it occur, would have no worse result than to necessitate the use of petroleum or some other liquid instead of water.

The arrangement of Fig. 21 is the simplest combination that can be conceived of for raising a head of water, consisting, as it does, of a single row of shutters jointed to the bottom and sustained in an erect positions by chains. The joint is of the form shown in Fig. 22, admitting a movement of 180 degrees. Assume the shutter to have some buoyancy, so that the free end will rise a little out of water. When the channel is open suppose the free end to lie up stream and to be latched down, leaving the navigable depth over it. The time comes for erecting the dam. The shutters having been unlatched, as near as may be, simultaneously, the free ends rise to the surface, and, in a few minutes, a head is raised which sets the shutters erect. They take the erect position as soon as the head becomes great enough to overcome their weight, and no dangerous shock can occur. The case is very different from that of shutters located on a weir which come into the erect position under the full pressure due to the depth, and give a violent jerk upon the chains. To drop the dam, the chains are cast loose by a suitable escapement, falling into water several feet in depth, so that they cannot strike the bottom or their seats with any force. To put them in position for the next raising of the dam, they must be reversed and latched with their free ends up stream. It is apprehended that the lack of attention which this combination has received, lies in the failure of inventors to realize the readiness and ease with which this operation of reversal can be performed. The only application which this device has received hitherto is in the temporary arrest of the flow over a weir. In this situation its reversal without an additional set of shutters would be difficult and dangerous, requiring powerful mechanism. In a wide channel, with a gentle current, the operation would be formidable if all the shutters were required to be raised simultaneously, or to be raised singly and remain erect;



HINGE FOR A MOVEMENT OF 180 DEGREES
FIG. 22.

but to raise each shutter singly, reverse, weigh down and latch it before proceeding to the next one, is in no sense a formidable, difficult or dangerous operation. A shutter 4 ft. wide, 18 ft. high, standing erect in water 8 ft. deep, moving with a velocity of 4 ft. per second, would not pull more than 150 lbs. on a line attached to the top. On throwing down the dam it would usually be advisable to weigh down the shutters and latch them down stream. This would be imperative if a flood were imminent. The work of raising and reversing them can be done as the workmen find time. As there is necessarily a depression on the down-stream side of the dam, it would naturally fill with sand or gravel during high water while the dam is down; but the overflow which takes place after the dam is raised will sweep these deposits away with certainty and thoroughness. Little deposit is to be apprehended on the up-stream side, as this presents a smooth, unbroken surface while the dam is down, and the stream is in no condition to make deposits while the dam is up. Mr. Frizell.

The desideratum of this system is a suitable escapement for casting loose the chain under a heavy strain. It is unnecessary to enter into these details. Such a device, operated by rods or chains can be originated in innumerable forms by any skillful mechanician. Modern engineering is under no necessity of pulling ropes or pushing rods to produce an effect at a distance from the operator, or at a point inaccessible to him. It has command of an agency whereby the pressure of a finger transmitted through a thin wire a distance of miles will set in motion a force capable of lifting a war ship out of the water, and this by arrangements which will remain in readiness for action for months and years. Fig. 23 represents an escapement designed on these principles. A rod, jointed to the bottom, carries at its free end a deep eye or short tube, with its axis horizontal. Each shutter is supported by two chains, each chain being attached to a short plug which enters this eye, not meeting, but leaving a short space between the two plugs. This space is occupied by a cartridge of explosive powder enclosed in a metallic case. The rod is hollow, and through the interior passes the electric wire. This runs to the center of rotation of the rods, and thence to the shore through the hollow trunnions on which the rods rotate. When, after throwing down the dam, the shutters are raised for reversal, a new cartridge is inserted, and the plugs confined in place by winding them with spun yarn to prevent them from falling

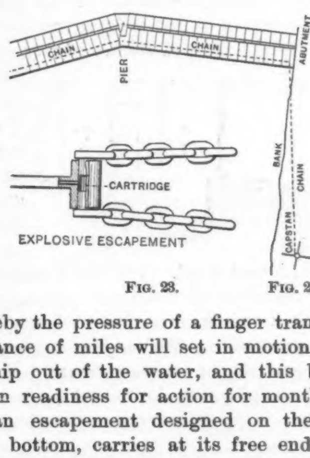


FIG. 23. FIG. 24.

Mr. Frizell. apart while loose. In lowering the shutter to its up-stream bed, the rod falls on the bottom, and the chain lies over it, thus avoiding kinks. No method of tripping by rods or chains could be devised with so little attachment.

This combination is believed to fulfill the seven conditions prescribed by the author, the only apparent exception being as to the fifth, viz.: Since the shutters could not be operated in close contact with each other, extraneous means would be required for tightening. It will be readily understood, however, that permanent packings could be introduced should the resulting advantage be found to justify the means. It is suggested for the consideration of those who are ambitious of distinguishing themselves in this branch of engineering that they would be more likely to attain success by studying and developing the two simple forms of shutter herein presented than by inventing new and more complex combinations.

Flash Boards.—In dams designed to raise a head for purposes of water power, the height of the dam is fixed by legislative restriction, by orders of Court, or by agreement with mill or riparian owners above. It is the height of the weir or overflow that is limited in this manner. The height to which water may rise is left to the control of natural agencies. This leaves a zone of land, above the level of the river, constantly subject to overflow. On this land no crops can be raised, no fences constructed. Neither can any permanent structure be erected which does not rise above the highest flood. Very little additional damage is done to this land by maintaining the water permanently at ordinary flood level, and such a privilege can very readily be obtained. Such privileges are of great value, not only as increasing the head acting on the wheel in low stages of the stream, but as enabling the water of nights and holidays to be held to a larger extent for use during working hours. The fixtures for accomplishing this result are called flash boards.

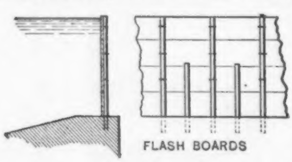


Fig. 25.

A dam owner always obtains this privilege under the expressed or implied agreement that the passage of the water over the weir shall be left free during high stages of the stream, otherwise the privilege of applying flash boards would simply amount to the privilege of raising the dam so many feet higher. The fulfillment of this obligation requires a form of flash-board barrier susceptible of being raised or lowered at will, without any reference to the stage of the stream. This condition is very imperfectly fulfilled by the methods in common use, which consist generally of boards resting against iron pins let into the dam, as shown in Fig. 25. This figure represents a system of

flash boards 4 ft. high, which is the greatest height ever attempted, heights of 2 and 3 ft. being much more common. Mr. Frizell.

This arrangement holds the water well enough, but if caught in a flood there is no relief till the pins are broken down by the pressure of the water or by floating ice, in which event the boards go down stream. When the water falls, the boards are left without support from the up-stream side, and are liable to fall off or be blown off by the wind, if not fastened to the pins. Fig. 25 indicates one mode of fastening them, viz., by small staples driven into the boards and embracing the pins. The joints are tightened by throwing in horse-dung, sawdust mixed with sand, or similar material.

On many large water-power streams the maintenance of a height of 6 ft. during low water would involve no material injury to any interest whatever. It has long appeared to the writer that the principles of movable dams which have received such development in recent years might be applied with great advantage to this case, and he predicts that the practicability of such applications will, before many years, become apparent to those who have such interests in charge. As showing the line on which such application will probably take place, Figs. 26 and 24 are given, representing the application to an existing dam not constructed with this purpose in view. To a new dam the principles could be more advantageously applied. The barrier consists of a line of shutters hinged to the top of the dam at the up-stream edge and supported, when up, by props resting near the down-stream edge.

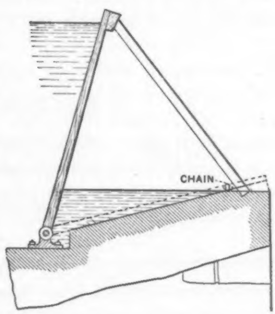
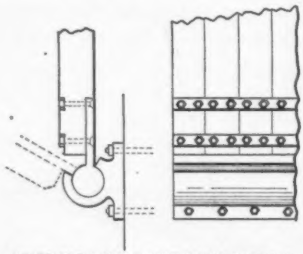


Fig. 26.

Before inserting the props, a chain is laid along the dam, between the props and shutters. This chain leaves the dam at the abutment and runs to a capstan, by winding in on which the props can be tripped and the shutters can be successively thrown down. The operation of raising the shutters is not required till the stream has fallen to a stage allowing the entire flow, at certain hours, to be drawn by the mills. At such times the water is below the cap of the dam, and the raising of the shutters is perfectly simple. The shutters would be liable to the same difficulty as the boards, being lifted clear of the props by the wind when the pressure is off, allowing the props to drop out. This would be obviated by employing the form of hinge shown in Fig. 27, limiting the movement of the shutter and allowing it to be strained up with considerable force before inserting the prop. The fall of the shutter would be cushioned by the water underneath

Mr. Frizell. it, and when lying flat on the masonry it could suffer no injury from floating bodies. The only injury to be apprehended from the fall of the shutter is from extraneous bodies lying on the top of the masonry, which should be guarded against. A stone thrown in at random would be very certain to be received in the cavity of the hinge. It might be thought that the wooden props would be liable to be caught under the shutter when the latter falls, but this could hardly occur. Before the shutter could catch the prop, the bulk of the water under it must be expelled, carrying the prop with it. The props need not be sacrificed, as are the boards in the ordinary arrangement, as they can be attached by cords to the main chain and hauled in with it.

Mr. Willard. MAJOR J. H. WILLARD.—Needle dams recommend themselves for moderate lifts on account of the small base required, the simplicity of parts, quickness of maneuvers, and the small amount of time and money for replacement or repair of any part. For high lifts the increasing weight of the needles would soon become prohibitory, not only because hand methods could not be used, but because of the loss of time in setting up, and the increased annual charge for operating. The needle dam does not seem suited for streams that bear much drift, though the controllable boom at Louisa is a clever and inexpensive device for keeping it away from the dam.



HINGE FOR A MOVEMENT OF 60 DEGREES

FIG. 27.

The writer, when visiting the lock and dam at Louisa last November, had no expectation of finding a tight dam, and was agreeably surprised at being able to walk the full length of the weir masonry dry-shod. The pool was drawn down about a foot to permit some repair to a pier, and there was hardly a trickle between the needles. The pass sill was under water, but the flow between the pass needles was insignificant—only a small gush or spurt here and there.

Having taken a paper* of some 16 pages, with plates, giving an account of some experiments in regulating pool levels on the Ardennaise Meuse, the pools under treatment fluctuating considerably from the operations of a great number of mills, the writer found that the problem had been solved by standing out as many alternate needles as seemed to be required by using a long-handled trident or fork and dropping in pins, so simple a method that the author hardly thought it of sufficient importance to mention.

Naturally, the author does not advocate his trestle form, but it certainly deserves trial on a large scale. The writer saw a model of full

* No. 17 of Annales des Ponts et Chaussées, 2d Trimestre, 1897.

size composed of several trestles, and has no doubt that a dam of equal lift with that of the navigable pass could be put in at no greater cost, and probably with considerable gain in speed of maneuvering. This form should allow considerable overfall. Mr. Willard.

However, the bear-trap forms, in spite of the great base required, and of the many objections raised against them, seem to be gaining friends, and are not unlikely to be used on a large scale. The idea of maneuvering a dam by the power of the stream itself, holding its crest at any height desired, or making almost an open river by the turn of a hand-wheel, is exceedingly tempting. Lumbermen have built many of different forms that have not been expensive or failures, and it is not beyond the skill of engineers to develop practical forms and to deduce trustworthy formulas for them under all conditions.

Unequal distribution of water pressures, and not merely improper proportioning of moving parts, seem to be the chief troubles, and the writer thinks he has solved the problem somewhat after the method of Major Marshall in his last improvement on the original bear-trap, and is glad to agree with him in believing that the simplest forms are the best to be worked at.

The Lang gate, though held to be a step backward on account of the idler, requires correct proportions only to insure its working under all conditions. Gates forming inclosed chambers demand the most careful machining to insure the parallelism of four axes, and slight wearing or shock may cause them to bind and stick, and, perhaps, tear out from their foundations. The inclosed forms, however, of which the Girard or Parker reversed seem most desirable, would probably be more efficient with respect to ratios of lift and base.

The writer feels that bear-traps are indicated for streams of great range between high and low-water discharge or of great sensitiveness, and the question of sedimentary deposit within or without seems to be of little moment, being a difficulty that can easily be overcome. Properly proportioned and sufficiently strong leaves can be built and the water pressures made reasonably uniform; but the way to do it is not to spend too much time on little models or differentials, but to build one form or another as thought suited to the conditions, after a careful study and a reasonable amount of mathematical discussion. This is practically what Captain Chittenden is doing at dam No. 1, Osage River, with every prospect of success.

As to initial head: if it should happen to fail at certain stages of backwater, or be insufficient from the first, any simple auxiliary form may be used, as in the double-shutter dams, to be dropped and secured afterward.

The writer would favor the use of compressed air, which should be admitted into self-discharging pockets of the main moving leaf; the air being compressed by turbine power or by inexpensive hot-air or coal-oil engines, such as are being installed on some of the new fortifications.

Mr. Fuertes. JAMES H. FUERTES, M. Am. Soc. C. E.—This paper, in which the author so thoroughly discusses the various types of movable dams in use in this country and abroad, cannot fail to be of practical utility by bringing out many of the valuable attributes of the movable dam which are at present but little appreciated.

The great obstacle to the more frequent use of these contrivances has been their expense, as compared with stationary dams. As the author has pointed out, however, the fact that their crests may be brought to a higher level relative to the extreme danger flood height, indicates that their use may, in certain locations, permit the construction of fewer dams in a given water course than would be possible with fixed dams; and although the individual movable dams may cost more than the individual fixed dams, the total cost of the series might not be much more with one type than with the other.

In addition to the requirements that a movable dam should fulfill, as enumerated by the author, it might not be out of place to add that it is desirable that the form of construction should permit the opening of the dam at different points in its length simultaneously; that its character should be such as to permit the passage of sudden floods; that in special locations, where damage from drift-wood or ice is to be apprehended, the form of dam should be such as to pass the floating masses with the minimum risk to the structure; and, that under certain conditions, in a cold climate, it should be possible to operate the dam when the pool is covered with thick ice. Further, leaving out the question of the topography and the physical characteristics of the location, two additional elements must be considered; these are the original cost of the dam, and the cost of maintenance and operation.

Needle dams cost less than any other form of movable dam at present in use, but in point of operation they are more expensive than some of the other forms. Under some conditions it is probable that the annual expense, including interest, sinking fund charges and cost of operation, may be higher for the needle dam than for some others, which cost more for installation. The writer, in these remarks, does not presume to imply a criticism on the form of dam chosen for the Big Sandy River, at Louisa.

Reliable figures regarding the cost of operating movable dams are rather difficult to obtain, and the writer hopes that in this discussion, much information of this kind may be brought out by those who have had experience with different forms.

On page 432 the author calls attention to the fact that there are, to his knowledge, no dams constructed wholly of needles except the one in this country. The reason for this is that it has been recognized in European experience, that it is very difficult to make a passage-way for floods through needle dams in a short enough period of time to give relief. This would be particularly true in flashy streams. For

this reason, generally, the weir will be found to be of some form permitting the water to flow over the top edge; such as the Chanoine wicket and its modifications, or the Desfontaines, the Girard, or Thénard weirs, or the Boulé gates. M. Poirée recognized the dangers from floating bodies and ice to such an extent that it was his practice to provide large and ample weirs at each of his dams for the passage of floating bodies, and to prevent the flooding of the tops of the needles and trestles. With a more rigorous climate than that of Kentucky, it is a question whether, in cold winters, considerable trouble would not be experienced at the Louisa dam. Mr. Fuertes.

In moderately cold weather a thin skin of ice will form on the pool. With the rapid rising of the river, due to a sudden thaw or to other causes, this ice will break loose and float down in large masses toward the dam. If, then, the needles of a needle dam are removed, the velocity of the water will increase, and the cakes of ice will be carried down through the trestles, or may pile up on each other and be difficult of removal. Eventually the dam may be entirely taken out, but the process will be slow and attended with considerable danger, both to the operatives and to the structure. If the cold is very intense, the ice formed above the dam may become very thick, and the water issuing between the needles will freeze, not only on the down-stream side, but between the needles themselves, and the whole dam will be frozen into a solid mass. It would be difficult to foresee the extent of the possible damages if a sudden flood should come down the valley when the dam was in such a condition.

One reason why the inconvenience due to ice has not been given more prominence is that in most existing cases the dams serve only to aid navigation, which is closed entirely in cold weather, and consequently the dams are frequently knocked down completely at the close of the season of navigation. When, however, the limits of the fluctuations of the surface of the water, from periods of drought to periods of extreme floods, must be kept between fixed points throughout the year for the development of power, the storage of water, or for other purposes, then the necessity of providing for the passage of ice and floating bodies will have a great influence on the determination of the type of dam to be used. The author admits that at Louisa, it would have been better had another form of dam been used for the weir.

Undoubtedly, the Poirée dam, particularly with the improvements suggested by the author, is simple, convenient and practical. It has been severely tested, and, although the oldest successful form of movable dam in use, it is still unquestionably the best for many situations. It is cheap and tight, and, for channels which do not require to be opened with great rapidity, pre-eminently suitable.

The idea advanced on page 491, describing plans the author has under way for a high-lift dam, with the needles on the down-stream side of

Mr. Fuertes. the trestle, has many points deserving commendation. This form of dam is, however, open to the same objections which apply to every needle dam where ice is to be expected. Where trouble from ice is not anticipated, it would unquestionably be an improvement on the older type.

The very expensive system of movable dams, consisting of the fixed overhead-bridge serving to retain the upper ends of the elements of the dam, will probably find its greatest usefulness in swift rivers, which in time of floods roll large boulders and great quantities of gravel along their beds. The effect of this would in time tend to destroy the trestles and other parts of dams which are lowered to the bed of the stream. In fact, even in such locations, their great expense would confine their applicability to the navigable passes. Dams suspended to overhead-bridges have one great advantage in the fact that they may be so arranged as to allow ice fields and large masses of drift wood to pass through them without injury to the structure. This is done at the dam on the Seine at Poses, where, by slightly raising the stanchions against which the curtains roll, their bottoms are disengaged from the sill, and the whole section of the dam, or as much of it as may be desired, is allowed to swing down stream hanging from the bridge, thus permitting the floating matter to escape.

The dam at Poses, consisting of seven spans, as the author has described, is so arranged that two of these spans can be removed and all the overhead works drawn up, to permit boats to pass at high water. At one side of this dam lies, first, a large lock, then a relief channel with Poirée needles, and then a small lock for light traffic. All the power for operating the movable weirs, lighting the premises, etc., is derived from a turbine wheel, located at the end of the overflow weir, at which there is, when the pool is full, an effective head of 13 ft., with a minimum of a little over 3 ft. when the dam is entirely removed. The power from this turbine is converted into electrical energy by a dynamo, and is stored in a large accumulator plant, from which it is drawn as required. The curtains closing the dam are raised by 4 electric cranes, each of which can be handled by one man.

The author's criticism of the curtain of M. Cameré seems, to the writer, to be in some respects unfounded. The curtains, at the dam at Poses, are 7.4 ft. in width. They are made of yellow pine, treated with a preservative, and vary from about 2¼ to 3 ins. in thickness. They are both durable and serviceable. One curtain that the writer saw laid out for repairs had been in use for 10 years, and there was but one ribbon which needed replacing. The author's criticism of the Cameré curtain, on account of its weight, is misleading. The weight of the needles at the Louisa dam, to fill a space equal to that covered by one Cameré curtain at the Poses dam, is just about the same as the

weight of the curtain, while there is very little difference in the lift at these two dams. In locations where power is available or necessary for the maneuvering of the dam, it would certainly be economy to be able to remove as much of the dam at a time as possible, and in such places the Cameré curtain would possess merits. In waters which run clear throughout the year, such as the Rhône as it leaves the Lake of Geneva, there will be no cause to fear that the spaces between the bars of the curtains would become filled with débris in rolling them up. For such locations the Cameré curtain is undoubtedly applicable; in fact it is at present in use there. Mr. Fuertes.

It may, at times, be of advantage to be able to discharge floods from the bottom, instead of from the top, of the dam. In the winter, when the ice is thick on the pool, a dam of needles or Boulé gates might be unwieldy, when, under similar conditions, the Cameré curtain could be rolled up from the bottom with comparative ease, and without danger, either to the operatives or to the structure. The danger to foundations, urged by the author against the Cameré curtain, due to the great velocity of efflux of the water from the bottom of the opening, need be no greater than would result from the overflow of the same quantity of water per unit of time, from the crest of a weir. Proper constructions are necessary in either case, and in any event the scouring effect when the curtain is rolled up would be identically the same as would result from the same width of opening in a Poirée dam of equal depth.

The author advocates the use of wide needles handled by power, and his suggestion has much to recommend it. It seems, however, that he is open to the charge of inconsistency when he condemns, so harshly, the invention of M. Cameré as a clumsy device with no good points, on the ground that it requires mechanical power to operate it.

The writer considers that the unit used by the author in giving an idea of the comparative cost of different dams is not satisfactory, on the ground that it is misleading. Two dams, for instance, of the same length, but of different heights, under similar conditions as to foundations and other requirements, would have different costs per linear foot; when the cost is given in this way it is very essential to state also the height of the dam. This unit is, however, in quite general use in France, where, also, the cost is frequently given per square meter of upright surface of the dam. Neither of these units should be used without stating the height of the lift.

The cost of the Louisa dam, viz., $245.66 per running foot, with a lift of 12 ft., is quite moderate in comparison with the cost of many of the high-lift dams in Europe. There are no needle dams in use which at all approximate this one in height of lift, and, therefore, no comparisons of cost can be given. The cost of several of the European

Mr. Fuertes. dams is stated to be as follows:* On the Saône, when the average lift is 7.54 ft., the dams for the navigable passes, with Chanoine wickets and trestles, cost about $244 per foot. The weirs with Poirée needles cost about $110 per foot.

Upon the Meuse in Ardennes, the average lift is only 5.9 ft., and the cost of the needle dam about $97 per foot.

Upon the Belgian Meuse, the Poirée dams on the navigable passes, with a lift of about 8.2 ft., as well as the weirs with Chanoine wickets and trestles, cost, on the average, $152 per foot.

Upon the Marne, the Chanoine wickets and trestles in the navigable passes, with an average lift of approximately 6.6 ft., cost about $244 per foot. The weirs with Desfontaine's drum wickets, having a lift of 3.3 ft., cost about $152 per foot.

The average cost of the weirs at Suresnes,† consisting of Boulé gates and Cameré curtains, with a lift of 11 ft., was about $866 per foot.

The dam at Poses, with a normal lift of 13.7 ft., cost, including very elaborate appurtenances, upwards of $1 700 per running foot. This statement, however, is somewhat misleading, and it should be explained that the actual cost of the weirs, the bridges, piers, masonry, foundations, etc., was about $975 per foot; and the balance was for the accessory works, lands and power plant.

The dam designed by the author, described on page 562, is very simple and ingenious. Some of the disadvantages that could be urged against it are, that it must be opened always from one end; that no section could be lowered until all those away from it on one side were down or falling; that it would be impossible to make an opening in it in the middle, or at any other desirable point or points. It would also be a difficult dam to maneuver in a rising river carrying much driftwood or running ice, and also in a swift river rolling boulders and gravel along its bed during freshets.

Mr. Maltby. F. B. Maltby, M. Am. Soc. C. E.—The author is to be commended for his exhaustive and painstaking care in the treatment of the subject. Only those who have undertaken the complete investigation of a subject of this nature can appreciate the vast amount of labor required in the preparation of such a paper.

The writer, as Assistant Engineer to Captain H. M. Chittenden, United States Engineers, has been engaged in the designing of the details for the drum weir to be built in the Osage River, and desires to present some further remarks on this type of a movable dam.

In considering the project for the construction of Lock and Dam No. 1 on the Osage River, a dam having a height of 16 ft. above extreme low-water was fixed upon as more nearly meeting the conditions existing and required.

* Guillemain, "Navigation Interieure."

† Boulé, "Le Barrage des Suresnes."

Mr. Maltby.

The necessity for the adoption of a movable structure arose from the fact that to avoid the flooding of valuable farm land the high-water cross-section at this point should be contracted as little as possible. It is estimated that the flood plane above a fixed dam would be raised slightly over 3 ft. above its level in the natural conditions. With the proposed structure the rise in the flood plane will be less than 1 ft. This difference of 2 ft. in flood levels would submerge a very considerable acreage, the damage to which would amount to much more than the cost of a movable dam over a fixed one.

In considering the type of movable dam to be built the following requirements were kept in mind:

(1) The movable portion should be capable of rapid and safe manipulation under the adverse conditions of a rapidly rising river filled with drift or running ice, with the flood arriving practically without warning and at any time of day or night and possibly during a severe storm of rain, snow or sleet.

(2) It should be possible to not only lower it, but to raise it under a full or partial head of water; for there will be times in short sudden rises when it will be desirable to discharge the flood without lowering the pool above. It will very seldom be desirable to allow the pools to come to the same level except during extremely high floods.

(3) It should be possible to lower a portion of it independently, for pool regulation, and to again raise it against the head between the pools.

(4) The cost should be kept as low as possible.

These rigid requirements cannot be met by the ordinary needle or wicket dams, and it is believed that all the above conditions are fully met in the design proposed. The proposed dam is quite fully described by the author. A mathematical discussion by Captain Chittenden* and a discussion of the strains in the members and a detailed estimate of cost† is also at hand. The dam consists of a fixed weir of concrete 9 ft. high, with a movable weir of structural steel sheeted with wood, having a vertical lift of 7 ft. It will be 750 ft. in length, divided into 10 sections each 75 ft. long. The sections will be separated by piers 10 ft. wide and 4 ft. higher than the crest of the weir.

These piers contain the conduits for the inlet and egress of water into a passage below the movable weir and also the valves for controlling the flow. The valves are actuated by hydraulic engines, which are in turn operated by a small pressure pump on shore.

Each section can be operated independently of any other, and the flow over the dam adjusted to a nicety. The whole dam or any number of sections can be raised or lowered by one man, at any time and under any conditions, in a very few minutes (except when the dam

* Journal of the Association of Engineering Societies, Vol. xvi, p. 250.

† Report of Chief of Engineers, U. S. A., 1897, p. 3956.

Mr. Maltby. is drowned out by back water from the Missouri River and there is no head). It is divided into independent sections by piers to comply with the third condition mentioned above. In a narrow river, or in any position where individual control of each section is not considered necessary, the piers may be omitted and sections of any convenient length be built adjacent to each other, and all operated from one conduit beneath them.

Since the weir is self-contained and all the surfaces maintain their same relative positions, the ends of the sections may be closed, thus permitting movement between sections, due to irregularity in time and rate of falling or rising, without leakage. The length of a weir under these conditions is only limited by the practical limits of the size of the conduits supplying water to the under or pressure surface.

Referring to Fig. 11, it will be seen that the movable portion is not only self-contained, but of rigid construction and has but one axis of rotation. The practical advantage of the latter point will be appreciated by those familiar with the constructive difficulties in building a long structure with four parallel axes, as shown in Fig. 7.

There are no angles in which drift can lodge, and when down, the fixed weir, the top of the movable weir and the apron form a smooth and continuous surface with no projecting obstructions and no depressions which may be filled with sand or gravel.

The cost is estimated at about $120 000. An estimate was made by a former engineer for a Chanoine wicket dam having a lift 1 ft. less than that now proposed, amounting to $182 500.

The above amounts show a very considerable difference in favor of the drum weir, in addition to the other advantages mentioned.

A model of the proposed dam, of full size in section and 10 ft. long, with water-ways for the inlet and egress of water to a chamber proportioned in size to the length, has just been built. It is enclosed in a tank of proper size, and water to operate it is furnished by a Cameron pump with 10-in. suction. It has been operated under conditions as near those to be met with in actual practice as it is possible to produce. The operations have been most satisfactory, and have served to increase the confidence in its behavior in actual service.

Mr. Hutton. Wm. R. Hutton, M. Am. Soc. C. E.—The author is to be congratulated on the success he has obtained in placing the "needles" of his dam by machinery, the practicability of which has been demonstrated by a year of operation.

As seen in France, the merit of the "needle" dam seemed to the writer to consist in the facility with which the maneuvering of the "needles" was executed, the lifts all being low.

The needle dams on the Belgian Meuse are too unwieldy to be operated except in case of necessity, and the regulation is therefore accomplished by means of the weir, *système Chanoine*.

Movable dams are certainly a great improvement upon fixed dams in those cases where they may be properly applied; but there are other considerations than the mere matter of height and, in a degree, of cost, which determine their application. Mr. Hutton.

On the Kanawha improvement the movable dams are placed where the river slope is less than 1 ft. to the mile. Where it is 2 and 3 ft. to the mile, fixed dams with locks of 15 ft. lift are substituted. Not only would the movable dams on this part of the river be too close for a proper economy, but the duration of the open navigation would be considerably less, owing to the greater slope, and the greater velocity of the current with a given quantity of water in the stream.

The author seems to attach undue importance to the depth of water below the dam as affecting its strength. When the water below reaches half way up the dam, the stresses in the needle bars will be $\frac{7}{8}$ as great as if there were none below; and in his suggested dam, 18 ft. high, with 6 ft. of water on the lower side, the pressure of the water below reduces the stresses only about 6 per cent.

The water in the lower pool is useful, in the case of the Chanoine wicket, in reducing the shock of its fall, and similarly with the released needles; but the needles and the wickets must be computed for the water pressure against their entire length, without relief from the lower pool.

If the Pontoise dam, described by the author, is excepted, the Big Sandy dam is the highest needle dam yet constructed; but the first Chanoine dams built on the Kanawha had the same height from sill to crest, and some of the later ones are said to be still higher.

In a Chanoine dam, before the invention of the Pasqueau hurter, the width of the opening (the pass) was a much more serious consideration than its height. In France, as the height of the wicket was increased, the width of the pass was reduced, so that at Port à l'Anglais on the Seine, when the height of the pool was made 12 ft., the width of the pass was reduced to about 94 ft.

The first two dams built on the Kanawha, Nos. 4 and 5, are 13 ft. high, and the passes are more than $2\frac{1}{2}$ times the width of the Port à l'Anglais pass, or about 248 ft. With this great width it was necessary that the tripping bar should throw two wickets by each of its first four movements.

The only experience then to be had was that of the French engineers, which was followed as nearly as possible in designing the tripping bars and machinery, having regard to the much greater forces to be dealt with. In other respects, where the results of observation and experience were less necessary, departures were made from French forms, some of which were adopted in France at about the same time.

On the Kanawha the trestles are spaced 8 ft. apart, or one trestle to every two wickets, French practice having placed a trestle to every

Mr. Hutton. wicket. If the latter method had been found indispensable, some other method of closure, using the trestles only, would have been adopted, as it seemed inexcusable to fill the river with trestles only to operate a second dam below. The double spacing of the trestles was rendered practicable by carrying the winch on a truck with three axles, so that in raising an intermediate wicket the lateral stress was brought upon the trestle through the wheels at the ends; at other times, the central wheels alone transmitted the stress.

An interesting feature in the construction of the foundations of the Port Villez dam was the rubble masonry blocks built on the shore and run to the water on a railway truck. The French masons are experts in the rare art of building rubble masonry solid, and their engineers in many cases prefer blocks of rubble masonry to blocks of concrete. The truck entering the water until the block was sufficiently submerged, a float came over it, took hold of the clevis built into the block and carried it, reduced in weight, to its place in the wall. The site of the pier was surrounded with these blocks, and the interior was filled to the upper surface with concrete deposited through the water, as is common in France, by means of hinged buckets, opening in the bottom.

Mr. Watt. D. A. Watt, Esq.—The subject of the paper has, as yet, scarcely received the attention it deserves. Movable dams have been more or less on trial before government engineers and navigation interests since their introduction in America, but their great cost has restricted their number and confined them to the more important rivers. The appreciation in which they are held abroad is shown by the fact that they have been built on streams where the combined length of pass and weir was scarcely 200 ft., and while their use may never become as extended in America, they could doubtless be constructed in many places without a cost greatly in excess of that of fixed dams, by employing high lifts.

Unfortunately there has been no precedent for high lifts in dams of the class required to cope with the sudden floods of the Ohio Valley, where the first movable dams have been built; for the high-lift dams of Europe are on rivers of slow regimen. There is a great difference, however, between the little dam at Basseville with its lift of 3¼ ft. and which could be practically operated by one man, and the great dam at Poses with its complicated machinery and its lift of nearly 14 ft.; yet the latter dam during the twelve years of its existence is said to have given every satisfaction, and its unusual height saved the construction of another lock and dam at Andé, 6 miles above.

Why the same success could not be attained with dams for swift rivers, if designed with proper skill, would be hard to say, and the experiments recorded by the author show that many of the objections hitherto urged can be overcome. The advantage of high lifts as regards cost and operation cannot be questioned, and might amount to

a saving of 30% over the cost of similar dams of such lifts as are now adopted. Mr. Watt.

The needle dam suggested by the author, with wide-span trestles, would seem well suited for deep passes, more so, perhaps, than the Chanoine system, as 20-ft. wickets might be difficult to handle in a rapid stream, besides being more expensive than a similar surface of needles. The Chanoine dam, it is true, has the advantage of each part being independent of the next, but the same result could probably be secured in a needle dam with trestles 20 ft. or more apart.

The "Thomas" trestle dam also seems a very practicable combination, and a dam of this kind could be operated more easily and safely than any present standard type, except the bear-trap or the drum wicket. With trestles for lifts higher than that shown, the writer finds that as the outlines are changed to suit the depth of channels the upward tension on the masonry begins to disappear, until, in a trestle for a depth of 16 ft. over the sill, the resultant pressures are all downward or horizontal. The advantages of this are, of course, that the heavy anchorages of masonry and of ironwork, required to hold down other types of dam, could be dispensed with. The writer would suggest the modification of placing the backs of the channels near together and stiffening the up-stream plate with an angle along each edge braced to the channels; in other words, forming an ordinary trestle with a 24-in. plate suitably attached.

Arthur M. Bowman, Esq.—The only bear-trap dams operating successfully are those built according to the most primitive type, having only the two flat leaves turning upon two fixed, parallel, horizontal axes, the lower leaf folding under the upper one. They can only be said to have been a success in short spans, not exceeding 60 ft. in length. In order to overcome the twisting and warping action so destructive to these flexible gates, the idea was conceived of constructing a dam in which the deflection of the gates, for a given distance, could be kept well within the limits of the elastic resistance of the material used in its construction. It is attempted to accomplish this by the stiffening of one of the gates, preferably the lower one, where the principal forces act, by transverse webs or girts, in a direction parallel to the axes, by which means it is believed that the working span may be increased to almost any desired length. The dam is connected, at either end, with a supply of water, under sufficient head to accomplish its initial movement by the opening of valves. When these have been opened, admitting the water under the gates, the force of the existing head will be immediately transmitted to the gate at the end next the valves. This end would immediately rise, while the more distant portion of the gate would remain at rest until the necessary lifting force reached it. This uniformly varying force causes a curve or wave to travel along the crest or free edge of the gate from the ends Mr. Bowman.

Mr. Bowman. toward the middle. The more flexible the gate, the more apparent will this curve or wave become, and the more injurious will be its effect upon the structure and the greater its tendency to lock and bind in its movement.

The calculations for deflection have been based upon the following considerations : - To cause the initial movement of the gates, a force slightly in excess of their weight must be applied. When the valves, admitting the water at the end, have been opened, the head, which is a maximum at the ends during this instant, diminishes uniformly toward the middle. It has been found accordingly, that (assuming the gate to be a cantilever held down by its own weight so that at a distance of 50 ft. from its end the gate remains at rest and is fixed) when loaded with a uniformly varying load between the limits of zero at the fixed end, and at the free end, an amount per lineal unit equivalent to the head necessary to cause the initial movement of the dam,

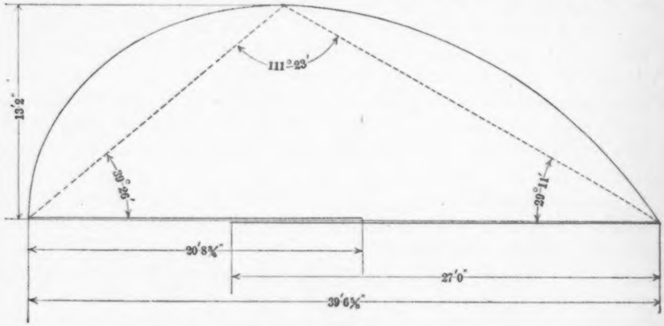


FIG. 28.

the deflection will not be greater than 1.839 ins. for a length of 50 ft., which is considered to be within the limit of safety to the structure. The following is the formula for the deflection, as deduced for the foregoing conditions :

$$D = \frac{19\, p\, l^4}{120\, E\, I}$$

from which the above deflection of 1.839 ins. was determined. Another important factor in eliminating deflection is the prevention of leakage. The gates should be made, as nearly as practicable, absolutely water-tight; thus reducing the loss due to velocity-head to a minimum, and thereby ensuring a maximum pressure-head and its rapid and uniform distribution throughout the entire length of the dam. Accordingly, by thus stiffening the gate with transverse webs, and also by making the dam practically watertight, thereby distributing the pressure more rapidly and uniformly throughout, it is be-

lieved that the deflection will become inappreciable and the wave Mr. Bowman. action along the crest so suppressed as to eliminate all injurious flexibility and allow the dam to be extended to any desired length.

The following is a mathematical solution of the problem of deflection as determined for the new bear-trap dam to be built at Dam No. 6, on the Ohio River, near Beaver, Pa. It consists of three spans of 120 ft. each, and is 13 ft. 2 ins. high, with a width of base equal to 39 ft. 6⅝ ins. between hinges; the upper gate being 20 ft. 8¾ ins. and the lower 27 ft. in width. Fig. 28 demonstrates the determination of these dimensions as the best proportions of the gates for a ratio of $\frac{8}{10}$ of load to lifting power.

Y = lower leaf = base × .6821;

H = maximum height = base × .33287;

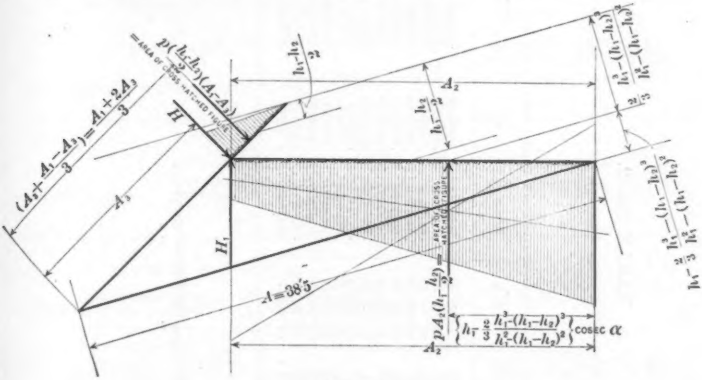


Fig. 29.

X = upper leaf = base × .5239.

n = ratio of the downward water pressure or load to the upward pressure or lifting power.

In continuing, let it be assumed that the gates are lying flat upon the river-bed, that the weight of the lower gate acts along the line of its center of gravity, and that an additional downward pressure, equivalent to the actual calculated force due to the weight of the upper gate at the point of contact of the two gates, acts along the same line. By referring to Fig. 29 and the accompanying table of forces it is found that:

$$H_1 A_2 = p A_2 \left(h_1 - \frac{h_2}{2}\right)\left(h_1 - \frac{2}{3}\,\frac{h_1^3 - (h_1 - h_2)^3}{h_1^2 - (h_1 - h_2)^2}\right) \operatorname{cosec} \alpha$$

$$H_1 = p \left(h_1 - \frac{h_2}{2}\right)\left(h_1 - \frac{2}{3}\,\frac{h_1^3 - (h_1 - h_2)^3}{h_1^2 - (h_1 - h_2)^2}\right) \operatorname{cosec} \alpha.$$

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TABLE No. 2.

		$\frac{h_1}{A_1}$		$\frac{A \times \sin \beta}{A_2}$							$A_2 \times \sin \alpha$
h_1	α	$\sin \beta$	β	$\sin \overline{\alpha + \beta}$	$\overline{\alpha + \beta}$	$\cos \alpha$	$\cos \beta$	$\cos \overline{\alpha + \beta}$	$\operatorname{cosec} \alpha$	$\operatorname{cosec} \beta$	h_2
1......	1° 17′ 13″	.0482392	2° 45′ 54″	.0706616	4° 03′ 07″	.9997478	.9988358	.9975004	44.525789	20.729914	0.6064
2......	2° 35′ 17″	.0964785	5° 32′ 11″	.1413232	8° 07′ 28″	.9969800	.9953352	.9899634	22.146259	10.365080	1.2192
3......	3° 55′ 04″	.1447178	8° 19′ 15″	.2119848	12° 14′ 19″	.9976632	.9894733	.9772733	14.635980	6.9100915	1.8448
4......	5° 17′ 35″	.1929570	11° 07′ 31″	.2826464	16° 25′ 06″	.9957359	.9812076	.9592236	10.840146	5.1825618	2.4907
5......	6° 43′ 35″	.2411963	13° 57′ 26″	.3533080	20° 41′ 01″	.9931168	.9704761	.9355451	8.5376699	4.1459832	3.1625
6......	8° 15′ 41″	.2894356	16° 49′ 27″	.4239696	25° 05′ 08″	.9896228	.9571975	.9056757	6.9594649	3.4550014	3.8796
7......	9° 54′ 37″	.3376748	19° 44′ 07″	.4946311	29° 38′ 44″	.9850785	.9412628	.8691019	5.8103830	2.9614287	4.6469
8......	11° 43′ 19″	.3859141	22° 42′ 02″	.5652927	34° 25′ 21″	.9791451	.9225344	.8248916	4.9221746	2.5912443	5.4854
9......	13° 45′ 34″	.4341534	25° 43′ 53″	.6359543	39° 29′ 27″	.9713029	.9008393	.7717264	4.2044026	2.3033374	6.4218
10......	16° 07′ 07″	.4823926	28° 50′ 30″	.7066159	44° 57′ 37″	.9606890	.8759561	.7075968	3.6019591	2.0730081	7.4959
11......	18° 57′ 50″	.5306319	32° 02′ 53″	.7772775	51° 00′ 43″	.9457236	.8476033	.6291584	3.0771869	1.8845511	8.7742
12......	22° 37′ 02″	.5788712	35° 22′ 16″	.8479391	57° 59′ 18″	.9230947	.8154198	.5300919	2.6002879	1.7275034	10.3835
13......	27° 53′ 07″	.6271104	38° 50′ 14″	.9186007	66° 43′ 21″	.8838858	.7789307	.3951848	2.1381104	1.5846167	12.6280

$x_1 = 10.5.$
$x_2 = 13.0.$
$p = 62.5$ lbs.
$L_u = 207$ lbs. = weight of upper leaf per lineal foot less the displacement.
$L_l = 577$ lbs. = " " lower " " " "

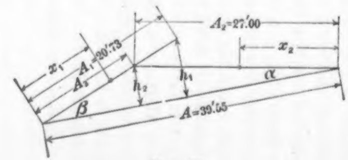

FIG. 30.

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TABLE No. 2—(*Continued*).

h_1	$h_2 \times \operatorname{cosec} \beta$. A_3	Friction. $\frac{\sin \overline{\alpha+\beta}}{100}$	$\sin \alpha$	Force of water pressure normal to upper leaf acting at point of contact of the two leaves $H = \frac{h_1 - h_2}{6} p \left(A_1 + 2 A_3\right) \frac{A_1 - A_3}{A_3}$ H	Pressure normal to the upper leaf due to its weight at the point of contact of the two leaves $D = \frac{x_1 \times L_w}{A_3} \times \cos \beta$ D	Load due to the component of $(H + D)$ taken perpendicular to the lower leaf $(H + D) \cos \overline{\alpha + \beta}$ $(H+D) \cos \overline{\alpha+\beta}$	Resistance due to rolling friction assuming a coefficient of .01 $(H+D) \frac{\sin \overline{\alpha+\beta}}{100}$ $(H+D) \frac{\sin \overline{\alpha+\beta}}{100}$	Pressure normal to lower leaf due to its weight at the point of contact of the two leaves $D_1 = \frac{x_2 \times L_c}{A_2} \times \cos \alpha$ D_1	$(H+D) \cos \overline{\alpha+\beta} + (H+D) \frac{\sin \overline{\alpha+\beta}}{100} + D_1 =$ Total downward pressure exerted at point of contact of the two leaves. Total load.	Upward force of water pressure normal to the lower leaf acting at the point of contact of the two leaves $H_1 = p\left(h_1 - \frac{h_2}{2}\right)\left(h_1 - \frac{2}{3} \cdot \frac{h_1^3 - (h_1 - h_2)^3}{h_1^2 - (h_1 - h_2)^2}\right) \operatorname{cosec} \alpha$ H_1
1......	12.57075	.0007066	.0224595	122.072	172.69	294.02	.2063	277.74	571.96	502.61
2......	12.63689	.0014132	.0451548	239.628	171.19	406.70	.5751	277.53	684.81	1001.71
3......	12.74753	.0021198	.0683248	348.317	168.70	505.27	1.0857	277.17	783.53	1493.59
4......	12.90845	.0028265	.0922499	443.418	165.22	583.82	1.7042	276.63	862.15	1973.98
5......	13.11150	.0035331	.1171281	522.885	160.88	639.69	2.3932	275.91	917.99	2438.81
6......	13.40106	.0042397	.1436893	573.873	155.21	675.70	3.0621	274.93	953.69	2880.27
7......	13.76133	.0049463	.1721058	598.935	148.67	649.73	3.6632	273.67	927.06	3292.47
8......	14.21396	.0056529	.2031623	567.228	141.07	584.27	4.0373	272.02	860.33	3664.50
9......	14.79167	.0063595	.2378460	542.470	132.37	520.80	4.3190	269.85	794.97	3981.52
10......	15.53910	.0070662	.2776267	451.438	122.52	406.14	4.0751	266.90	677.12	4221.04
11......	16.53552	.0077728	.3249721	316.336	111.41	269.12	3.3364	262.74	535.20	4345.77
12......	17.93747	.0084794	.3845728	148.385	98.808	131.03	2.0926	256.55	389.67	4284.36
13......	20.13678	.0091860	.4677027	6.964	84.974	36.25	.8375	245.56	282.65	3865.46

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$$H\,A_3 = p\,\frac{(h_1 - h_2)}{2}(A_1\,A_3)\left(\frac{A_1 + 2\,A_3}{3}\right)$$

$$H = p\,\frac{(h_1 - h_2)}{6}\,(A_1 + 2\,A_3)\,\frac{A_1 - A_3}{A_3}.$$

When

$$\alpha + \beta = 0$$

$$H = 0$$

and

$$D + D_1 = \frac{x_1\,L_u}{A_3} + \frac{x_2\,L_l}{A_2}$$

$$= \frac{x_1\,L_u}{A_1 - A_2} + \frac{x_2\,L_l}{A_2}.$$

$$= \frac{10.5 \times 207}{12.55} \times \frac{13.0 \times 577}{A_2}$$

$=451$ lbs. per lineal foot at the point of contact of the two gates. But, 451 lbs. at the point of contact is equivalent to $\frac{451 \times 27}{13} = 936.7$ lbs. acting along the line of the center of gravity for each lineal foot of dam. With an equivalent upward water pressure (or rather a water pressure slightly in excess of this amount), acting uniformly over each foot of the dam at the same instant, the gates would rise without showing any deflection. But, since all flexible gates exhibit deflection, it is assumed that the lifting force decreases in passing from the end toward the middle of the dam. For the purpose of the calculation, assume that it has its maximum value 936.7 lbs. per lineal foot or 78.06 lbs. per lineal inch at the end and diminishes to zero at a distance of 50 ft. from the end. The formula for deflection can then be deduced as follows:

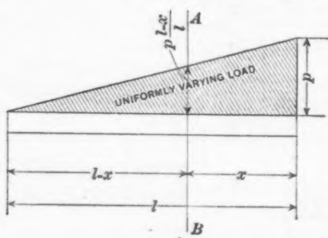

FIG. 31.

Let $p =$ pressure per lineal inch at outer end of cantilever.

The total load varies uniformly from zero at the fixed end to p at the other end.

Take a section $A\,B$ (Fig. 31) anywhere in the cantilever distant x inches from the end; let $l =$ the span in inches. Then since the load per lineal inch at any point is proportional to its distance from the fixed end, the pressure per lineal inch at $A\,B = p\,\frac{(l - x)}{l}$. Now, to determine the bending moment at any section $A\,B$, consider the portion of the beam to the right of the section; the only force acting upon this part of the beam is the portion of the uniformly varying load lying to the right of the section and is

$$p\,x - \left(p - p\frac{l - x}{l}\right)\frac{x}{2}$$

The bending moment

$$M = p\,x \times \frac{x}{2} - \left(p - p\frac{l-x}{l}\right)\frac{x}{2} \times \frac{x}{3}$$
$$= \frac{1}{2}\,p\,x^2 - \frac{1}{2}\,p\,\frac{x^3}{3\,l}$$
$$= \frac{1}{2}\,p\left(x^2 - \frac{x^3}{3\,l}\right)$$

Now, the equation to the beam from which the deflection is determined is

$$\frac{M}{I} = \frac{E}{r}$$

Where M = bending moment.
I = moment of inertia.
E = modulus of elasticity.
r = radius of curvature.

From calculus it is known that

$$r = \frac{\left(1 + \left(\frac{d\,y}{d\,x}\right)^2\right)^{\frac{3}{2}}}{\frac{d^2\,y}{d\,x^2}}$$

where the curve is referred to rectangular axes and x and y are the co-ordinates of any point on the curve.

Hence :

$$\frac{\frac{1}{r} = \frac{d^2\,y}{d\,x^2}}{\left(1 + \left(\frac{d\,y}{d\,x}\right)^2\right)^{\frac{3}{2}}} = \frac{M}{E\,I}$$

but for y max.

$$\frac{d\,y}{d\,x} = 0,$$

and, therefore,

$$\frac{d^2\,y}{d\,x^2} = \frac{M}{E\,I}$$

therefore,

$$\frac{d^2\,y}{d\,x^2} = \frac{p}{2\,E\,I}\left(x^2 - \frac{x^3}{3\,l}\right)$$
$$\frac{d\,y}{d\,x} = \frac{p}{2\,E\,I}\left(\frac{x^3}{3} - \frac{x^4}{12\,l}\right) + c$$

but when

$$\frac{d\,y}{d\,x} = 0, \text{ then } x = l$$

therefore,

$$c = \frac{p}{2\,E\,I}\left(\frac{l^3}{3} - \frac{l^3}{12}\right)$$
$$= \frac{p}{2\,E\,I}\,\frac{l^3}{4}$$

Mr. Bowman. therefore,

$$\frac{d\,y}{d\,x} = \frac{p}{2\,E\,I}\left(\frac{x^3}{3} - \frac{x^4}{12\,l} + \frac{l^3}{4}\right)$$

$$y \text{ max.} = \frac{p}{2\,E\,I}\left(\frac{x^4}{12} - \frac{x^5}{60\,l} + \frac{l^3\,x}{4}\right)$$

but when y is a maximum $x = l$.
Therefore,

$$y \text{ max.} = \frac{p}{2\,E\,I}\left(\frac{l^4}{12} - \frac{l^4}{60} + \frac{l^4}{4}\right)$$

$$= \frac{p}{2\,E\,I} \times \frac{l^4 \times 19}{60}$$

$$= \frac{19\,p\,l^4}{120\,E\,I}.$$

Now, to determine the moments of inertia of the stiffening girts or the value of I_s:

From Fig. 32 $I = \frac{b\,h^3}{12} - \frac{b_1\,h_1^3}{12} - \frac{b_2\,h_2^3}{12}$.

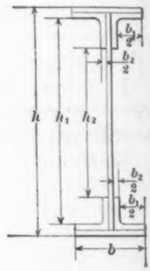

FIG. 32.

For Girt No. 1:

2 angles 3" × 3" × $\frac{3}{8}$"
1 web pl. $19\frac{9}{16}$" × $\frac{1}{4}$"
$I_1 = 496.8$.

For Girt No. 2:

4 angles 4" × 3" × $\frac{3}{8}$"
1 web pl. $36\frac{1}{16}$" × $\frac{3}{8}$"
2 cover pl. $8\frac{3}{8}$" × $\frac{3}{8}$"
$I_2 = 6\,515$.

For Girt No. 3:

4 angles 5" × 3" × $\frac{3}{8}$"
1 web pl. 48" × $\frac{3}{8}$"
2 cover pls. $10\frac{3}{8}$" × $\frac{3}{8}$"
$I_3 = 15\,226$.

For Girt No. 4:

4 angles 4" × 3" × $\frac{3}{8}$"
1 web pl. $35\frac{13}{16}$" × $\frac{3}{8}$"
2 cover pls. $8\frac{3}{8}$" × $\frac{3}{8}$"
$I_4 = 6\,408$.

For Girt No. 5:

4 angles 3" × 3" × $\frac{3}{8}$"
1 web pl. $20\frac{1}{8}$" × $\frac{1}{4}$"
2 cover pls. $6\frac{1}{4}$" × $\frac{3}{8}$"
$I_5 = 1\,379.6$.

I_s is equal to the sum of the moments of inertia of all the girts.

$$I_s = I_1 + I_2 + I_3 + I_4 + I_5$$
$$= 30\,025.4$$

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By adding them together it is assumed that they act simultaneously at the line of the center of gravity of the lower gate, and that the girders swinging on the hinges are perfectly stiff and act without deflection.

E, the modulus of elasticity, depends upon the material, and for steel is taken at 29 000 000.

Hence, referring to the formula for deflection and substituting values for symbols:—

$$y \text{ max.} = \frac{19\, p\, l^4}{120\, E\, I}$$

$$= \frac{19 \times 78.06 \times 600^4}{120 \times 29\,000\,000 \times 30\,025} = 1.8396 \text{ ins.}$$

With so small a deflection it may be concluded that the objectionable tendency, in a long gate, of warping and twisting, has been practically removed, and that with proper handling its crest will easily rise uniformly from end to end.

Mr. Thomas.

B. F. Thomas, M. Am. Soc. C. E.—In closing, the author desires to express his gratification at the reception given to his efforts, both in the discussion and in private letters from engineer officers and civil engineers, and to cordially thank those who, whether members of this Society or otherwise, have contributed to the literature upon the subject of movable dams in this discussion, and who have, with gentle hand, pointed out a few of the author's errors of statement and omissions of facts, apparently well known to those engineers whose metropolitan surroundings have enabled them to keep posted on all new ideas and improvements.

The account given by the author was only intended as a *résumé*, in so far as it treated of other dams than that built by him at Louisa, and most of the information therein given was compiled from foreign publications of no very recent date. This has led to some errors which are corrected by Mr. Vernon-Harcourt in his discussion. It was hoped that the paper might stimulate those in actual charge of dam construction and students and observers of the same to further remarks which would be of value to the profession. While it has failed to elicit anything from those in immediate charge of movable dam construction in America, it has brought forth valuable information and suggestions from those who have studied the subject and those who have observed the practical working of movable dams in Europe and in the United States.

The author confesses to disappointment that the idea dwelt upon in the paper to the exclusion of all others, that, in future, dams should be built of higher lift than heretofore, has not been more fully discussed. It is of vital importance to secure for a dam every available inch of height, in order to lessen the number of locks to be passed and decrease the aggregate cost of improvements, and this feature should

Mr. Thomas. receive the most thorough investigation and study by engineers. The type of dam, while of great importance, is secondary to the height which can be given to it.

Some of the discussions will now be briefly touched upon, after which will be given a short description of the new method of simultaneously placing the large needles in the Louisa dam, which has been in successful operation since January 12th, 1898, and which has rendered it possible to apply needles of any desired dimensions to dams on rivers of great widths.

Mr. Vernon-Harcourt's remarks are valuable as coming from a gentleman of wide opportunity for observation of the actual working of movable dams, as well as an author of undoubted ability, and the author is grateful for his correction of a statement in regard to the Krantz dam, which statement was made upon the authority of a French treatise on river improvement published about 1875. The author had noticed that in the later descriptions of the Port Villez dam no mention was made of the Krantz weir, but he had no idea of the abandonment of the work.

The author had read the description of Indian weirs by M. Buckley, mentioned by Mr. Vernon-Harcourt, and was aware of the adoption of the hydraulic brake for regulating the rise of the Thénard counter shutter, but he had been informed that, even with this contrivance, the chains would now and then give way through the failure of the brake to act or for unknown cause. As to the drum weirs of the river Main the author had very meager information, and even that seems to have been incorrect. To those desiring to study this form of weir, reference is made to the papers mentioned in Mr. Vernon-Harcourt's discussion, and to M. Timonoff's work upon the subject of drum weirs published in the Russian language at St. Petersburg.

The statement by Mr. Vernon-Harcourt that "sliding panels are more readily put in place or removed, and serve better than heavy needles for adjusting the water level above the dam" will have to be modified somewhat since the successful adoption of the plan for placing the needles simultaneously. The panels are, undoubtedly, well adapted to pool regulation, but the spans of the trestles must be so narrow that the spaces will not permit the passage of drift-wood after the planks have been taken out. Again, the maneuvers would be entirely too slow for a river which rises as rapidly as most American streams.

Most of those forms of dam which must of necessity be put in and taken out very slowly, such as Boulé gates, Cameré curtains, etc., cannot be considered for streams similar to the Big Sandy, which carries drift on all rises, but may well be adopted on European rivers which rise quite slowly and carry very little, if any, débris. The wide spacing of the trestles will overcome the objection often raised

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against their use in both wicket and needle dams, and accidents similar to that at Davis Island, wherein the trestles were destroyed by drift piling up against them, would probably be impossible, or at least improbable. There is no difficulty whatever in making the spans 20 ft. and it would be very difficult to destroy the trestles for such spans because they would, of necessity, be very strong. Drift, in such quantities as to prevent the complete lowering of the dam, would rarely accumulate in spans of that width.

The statement that "where large masses of drift are carried down, and sudden floods occur, a wicket dam without a foot-bridge would provide the most convenient dam, especially if furnished with improved tripping arrangements" is at variance with experience in the United States. The drift permeates everything and blocks the lowering by becoming entangled in the horses of the wickets. As soon as a few wickets have been lowered the drift rushes through the opening, only to return below the part yet standing and get in the way. If small-section dams, such as wickets, gates, needles, etc., are to be put in on the passes, one of the weirs should be provided with a drum, bear-trap or other contrivance. not operated in sections, but as a whole, through which the drift and surplus water may be passed until it is time to begin opening the pass, which time will not arrive until the head between the pools has been materially reduced by the fall of water above and the rise below the dam.

Mr. Fuertes states that "it is desirable that the form of construction should permit the opening of the dam at different points in its length simultaneously." Wicket dams fully answer this requirement, and yet the author has never known one to be opened except continuously from one end. His statement, that the operation of needle dams is more expensive than some of the other forms, is open to question. The Louisa dam requires only three men, while the wicket dams of the Great Kanawha and Ohio employ from six to eight men in operating. Excepting dams which are operated by the force of the water, of which there are few on navigable rivers, it is doubtful if a more economically operated dam could be found than the needle dam. Considering the amount and character of the commerce, the operation of the Kanawha wicket dams is carried on at a remarkably low cost—about $2 500 per annum each. Even the fixed dams on the same river and on many other rivers cost more, and some of them more than twice that amount.

The cost of operating the Louisa dam will average about $2 200 per annum, which includes gauge observers at up-river points, telephone rent, telegrams, lights, ordinary repairs, etc. This will be still further decreased upon the completion of the system, as then it will only be necessary to keep the third man during the low-water season, probably, and the expense of the telephone and gauge-reading service will be apportioned.

Mr. Thomas. Mr. Fuertes states that "it has been recognized in European experience that it is very difficult to make a passageway for floods through needle dams in a short enough time to give relief." There is not in existence a small-section dam (wickets, gates, etc.) which can be opened with an approach to the speed attained at the Big Sandy needle dam. The time for removing the needles, as well as for placing them after they are made ready, is now measured in seconds, not minutes or hours. The weir, 140 ft. long and 7 ft. high, has been opened in 58 seconds; the pass, 130 ft. long and 13 ft. high, has been put in place, after the needles have been taken from the water and set up on the shelves, in 10 seconds.

Mr. Fuertes has pointed out the danger from ice, and there is no doubt that this is a great enemy to movable dams of any form, and particularly to those built of small sections and requiring extraneous power for their operation. The remedy, so far, applied both in America and Europe, is to lower the dams upon the approach of rigorous weather, but this often causes considerable loss and inconvenience to those having loaded craft in the pools, as such craft become stranded and often ruined, and their cargoes a total loss. This is particularly noticeable in the destruction of coal flats and barges loaded during the summer with the expectation of getting out before cold weather, and held in the pools awaiting a rise below the system of dams.

With needle dams a remedy might be applied, which would work in all cases except those where unusually heavy ice had formed, and that is the system of wide-span trestles with the needles on the downstream side, mentioned in the paper. The needles could be readily released and saved; the question of danger and injury comes when the lowering of the trestles is undertaken.

The author's criticism of the curtain dam, noted by Mr. Fuertes, had particular reference to its use, as at Port Villez, in connection with trestles. At Poses it can well be used, as nothing has to be carted ashore, but even there the objection of opening from the bottom applies. In addition to the objections thereto noted by the author, but first mentioned by one of the most eminent engineers of France, is the one that the curtains roll up unevenly, and become jammed against each other or against the trestles. This was obviated at Suresnes by M. Boulé by placing them only on alternate bays, and using his sliding gates for the intermediate spaces.

Its weight would be much less objectionable were it a solid gate which could be permitted to fall and float up like so many connected needles. Of course, for the bridge dam at Poses, the weight is not a serious obstacle. It is not the necessity for using mechanical power for operating the curtain that condemns it, when compared with wide needles, but the necessity of running it ashore then and there while

engaged in opening the dam, before another curtain can be raised. Needles are secured beforehand, and no attention need be paid to them, after being once removed, until the whole dam is out of the way. Mr. Thomas.

The curtain dam was not condemned by the author "on the ground that it requires mechanical power to operate it," and he cannot be charged with inconsistency, as stated by Mr. Fuertes, in advocating the use of wide needles manipulated by power.

Mr. Hutton has called attention to the small effect of the back-water in reducing the stresses in the needles. As stated by him, all dams should be designed with the view that at some time there might be no back pressure, for instance, in making repairs to the apron, etc. The Kanawha dams have the same total height as the Louisa dam, 13 ft., but much less head. Dam No. 6, Ohio River, upon which the author is now engaged, will have a height of 13 ft. 2 ins., and will be the highest wicket dam in the United States. M. Pasqueau first proposed wide-span trestles for the wicket dam at La Mulatière, where he made them 9 ft. 8 ins.

Mr. Hutton's statement, in connection with the Kanawha improvement, that "it seemed inexcusable to fill the river with trestles only to operate a second dam below" might quite as well be applied to the 8-ft. as to the 4-ft. spans. While the Kanawha improvement is a monument to all concerned in its design and execution, and a model of beautiful, substantial and economical workmanship, yet it is to be regretted that, with such high banks and solid foundations, dams of greater lift and complete in themselves, without additional foot-bridges (in themselves, and with their foundations, a source of great expense) were not constructed.

Mr. Frizell's contribution contains many useful suggestions outside the beaten paths.

The counter shutter of Thénard, Fig. 20, is inadmissible, in many locations, because of the sunken drift and débris which comes against the shutters when they are up and prevents their complete lowering. The down-stream shutters will act perfectly, and it is only necessary to find a means of raising them easily and quickly to have a successful dam.

For a narrow stream, for which the author expects to design some movable dams he has had in view, in place of the counter shutters, he proposes to use a suitably constructed floating truss, carrying, in a vertical position on its down-stream side, a set of needles. The float would be attached to the masonry at each end (lying across the river) and the needles would be dropped, as is now done from the shelves at the Louisa dam, thus closing the waterway. The shutters would then be raised, from the top of the float carrying the truss, by suitable hoisting machinery thereon. As soon as the river rises and flows over

Mr. Thomas. the needles and fills the space between them and the shutters, the pressure will be relieved, the needles will float up, and the float can be removed.

Since writing the paper the experiments on improved methods of placing the needles in the Louisa dam have been completed, and the system is now in successful operation. All the needles are placed one by one on shelves attached to frames which stand on the sill of the pass, and are supported at the top against the trestles. The bottoms of the needles are just above the water, so that the flow is not interrupted. When all is ready the releasing of a light chain, which connects the triggers supporting the shelves, permits the shelves to revolve, and the needles drop simultaneouly into the water and come to rest against the shoulder of the sill. Thus they go in without increasing the velocity of the current more than is caused by raising the trestles and placing the frames. It is not even necessary to close the lock gates until the needles are in place against the sill, but this must be done speedily thereafter. The frames are so constructed as to guide the needles into place and prevent the current from carrying them down stream on to the sill. The success of this device completely solves the problem of the use of wide needles, and it only remains to increase the spans of the trestles and place the needles below the line of the trestles, instead of above, to obtain a needle-dam which will be adaptable to any desired width of stream and be lowered at the rate of from 100 to 150 ft. of dam per minute on the weir and from 50 to 100 ft. per minute on the pass, if necessary or advisable, and of placing the needles at the rate of 4 ft. of dam per minute with three men.

Placing the Needles.—The needles in the pass of the Louisa dam weigh about 275 lbs. each and are 12 ins. in width. They are placed by three men with the greatest ease and dispatch, and it is possible to close passes of any width without increasing the head beyond a few inches while so doing. During the coming season it is proposed to use a dozen needles, each 3 ft. or 4 ft. in width, as wide as a Chanoine wicket, for experimental purposes. The method is as follows:

A series of light frames having upright slats or rods, resting on the sill at the bottom and against the trestles at the top, is placed across the entire pass. Just above the water level, at the stage at which it is proposed to place the needles, each frame carries a little shelf fastened in the middle on a trigger, the down-stream end of which is held in place by an upright lever. The two ends of the shelf are supported on hinges connected with the frame. The simultaneous throwing of these levers, when the needles are standing on the shelves, will release the triggers and permit the shelves to revolve and drop the needles into the water, when the slats or rods of the frame will guide them into place and prevent their being carried over the sill. For the purpose of releasing the triggers simultaneously, all the levers

Mr. Thomas.

are connected with a light chain stretched across the pass and resting in claws in the tops of the levers. One end of the chain is made fast until all is ready, when it is released, which operation permits all the levers to fall, thereby releasing the triggers and causing the needles to drop into position instantly. This invention has proved wholly satisfactory, and permits the dam to be erected with the regular force of three men, using the steam derrick on the needle-boat for placing the needles on the shelves. A number of the needles may be placed above the frames, directly against the sill, and thus act as guides to the others if desired. This method will readily admit of the use of needles 4 ft. wide, weighing over 1 000 lbs., and of placing them on the shelves ready to drop at the rate of one needle per minute. In a new dam there is no doubt that the trestles can be so designed that the needles can be placed simultaneously without the use of frames.

Regulating the Pool.—When the pool has once filled it is necessary to provide for the escape of the surplus water. Authorities on movable dams have pointed out the dangers liable to arise from permitting the needles to overflow, but, with due regard to these authorities, the writer can say that there is no danger whatever in allowing an overflow of a few inches in depth; in fact, were the needles to be replaced, he would certainly recommend a design which would permit almost an unbroken spillway along the crest.

The construction of the needles for this dam is such that only about one-third of the width of each needle can be submerged without raising the pool several inches above its normal height, and it was necessary to adopt some other means of wasting the surplus water, particularly on a rising river. This method consists in *re-poussing* or pushing back the heads of alternate needles. As there is a pressure of some 550 lbs. on the head of each weir needle, it was necessary to devise means of pushing them up stream. A home-made ratchet-jack was used for some time with success, but as it was rather slow for a rising river, it was decided to devise something which would do the work more rapidly. While engaged in the study of this, the writer was surprised to find in De Lagrene's "Cours," not only a suggestion that needles might be *re-poussed* (although it had not been done) and held back by sticks placed across them and against the adjacent needles, but also that he described a jack which he thought might be used for the purpose. The needles at the Louisa dam were not of a design suitable for being moved with such a device (the lever being inserted behind the needles), but another was soon designed, after a practical test of a model or two, which has, up to this writing, given good satisfaction. It is little more than a forked wooden lever, the two legs resting on the up-stream faces of the adjoining needles while a catch drops over the head of the needle to be pushed back. By pushing the lever up stream the head of the needle follows, the legs passing each side and sliding slightly

Mr. Thomas. on the other needles in turning. By describing with the lever an angle of 90° the head of the needle is carried 12 to 15 ins. up stream and the pin for holding it is introduced with a pair of tongs. A light, floating platform is used, in order to pull the lever over to the proper amount, but the device can be made, so that by bending the handle down to the foot-bridge, the whole operation can be performed without the use of a float. To replace the needles, the operation of the lever may be reversed, or they may be checked down with a line passing around a snubbing post on the float. It is probable that the lever will soon be improved by placing rollers at the ends of the legs and by arranging it so that the entire work may be done from the foot-bridge, without the use of a float.